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CONTENTS

The Pursuitmeter: WALTER R. MILES, 77.

Further Techniques for Inspiration-Expiration Ratios: HAROLD E. BURTT, 106.

Complex Signs in Diagnostic Free Association: C. L. HULL and L. S. LUGOFF, 111.

Effects Simulating Fatigue in Simple Reactions: F. L. WELLS, C. M. KELLEY, G. HUBBERT, 137.

Subjective Perpendicular: KARL M. DALLENBACH, 143.

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THE PURSUITMETER

AN APPARATUS FOR MEASURING THE ADEQUACY OF NEUROMUSCULAR COÖRDINATION DESCRIBED TOGETHER WITH ILLUSTRATIVE RESULTS[1]

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INTRODUCTORY

In a recent paper (1) was described a very simple apparatus called 'A Pursuit Pendulum' which is well adapted to measuring the success of an individual's reaction and eye-hand coördination to a moving object. In this case the test is discontinuous. The reactor makes a number of separate trials after each of which there is an interval when he may relax and then readjust himself before giving the next signal for the release of the pendulum. This corresponds to the usual reaction test, measuring as well the coördination following the reaction. To provide a continuous task of this nature, requiring reaction and eye-hand coördination (the natural accompaniment of reaction) has appealed to the writer as very desirable. It has been worked out in the form of an electrical equipment which, although rather elaborate and expensive, produces results which have fully repaid the expenditures. Before entering on a description of the Pursuitmeter and as a basis of judging its merits, it may be well to describe with some detail the ways in which other workers have met the general problem.

[1] In shorter form this paper was prepared for the American Psychological Association, December 30, 1920, and a communication on the subject was made to the Congress of Physiology, Paris, July, 1920.

The usefulness of a continuous test requiring discrimination and choice reaction has appealed to many, and several combinations of apparatus have been devised to this end. As an example, Seashore (2) described in 1902 what he termed a 'Psychergograph' which was developed as a means "(*a*) to call forth a relatively simple and definite complex of mental activity (*b*) to repeat the same for any desired length of time without interruption and (*c*) to measure the amount of work done, the time taken, the quality of the work, and fluctuations in speed and quality." His apparatus consisted of a stimulator and a recorder, the former being a clockwork mechanism carrying a disc on the periphery of which four symbols were repeated over and over in chance order. The symbols were viewed one at a time through a small window. Each reaction operated, by means of electro-magnets, an escapement which exposed a new signal for reaction. The reactor thus made his own tempo. Each of the four reaction keys closed an electric circuit and a graphic record was made on paper tape by four ink pens while a fifth pen provided a time line. When a test had been started all was quite automatic so far as the experimenter was concerned. The pressing of a key, whether it was the right or wrong reaction, changed the symbol, hence aside from reading the reaction time the graphic record had later to be interpreted, when determining the number of errors made, by comparison with the known order of the symbols on the disc. Having used the 'Psychergograph' at Iowa, its many excellent features are personally known to me.

McDougall (3) in 1905 published a description of an apparatus for the study of concurrent mental operations and mental fatigue which has later been modified and is now referred to as 'The Rivers-McDougall Fatigue Machine.' Circular targets, 2 mm. in diameter, are printed in as irregular a manner as possible along the length of telegraph tape. They are spaced at a constant distance of 5 mm. along the length of the paper and given a maximal lateral deviation of 12 mm. A continuous band of such paper is caused, by means of a weight-driven clockwork, to be exposed through a slit. The

reactor, with a needle-pointed stylus, tries to spear each target as it is presented to view. The difficulty is increased by quickening the speed, until maximal effort is required from a particular subject. The distance from the prick mark to the target is measured to determine the efficiency of performance. This apparatus has been used by McDougall and Smith (4), Burt (5), M. Smith (6), and others with very good results. The Rivers-McDougall machine is very compact and has the practical advantages of easy portability and independence of laboratory conditions.

More recently McComas (7), among others, has arranged a set-up for recording continuous discrimination reactions which in practice is quite like Seashore's arrangement except it is more quiet in its operation and employs for stimuli four colored lights exposed behind one small ground glass window. A reaction, by pressing the appropriate one of four keys, extinguishes the light which has appeared as a stimulus and causes a secondary electric clock placed opposite a circle of radiating copper contacts to move forward 1/60 revolution and so close a circuit and present the next stimulus. The four stimuli are presented in chance order and there are 60 in the series until it begins to repeat. The wiring arrangement is very ingenious. On the kymograph record which is well condensed one signal records all reactions while a second marker records only correct reactions. When later measuring the time values the errors are thus directly revealed.

A usual part of such apparatus and a seemingly essential feature, as there has not appeared any good way for taking care of the matter otherwise, is the graphic record. Individual reactions, 'single acts,' may be recorded directly from reading the chronoscope at the time of the experiment. Continuous reactions have on the contrary to be measured out in reference to time lines on paper tape or kymograph tracings. There are, doubtless, some instances when it is desirable to measure these reactions individually 'at leisure' and to definitely separate the error score and the time score for the proper analysis of speed, of quality and variability

of performance. Practically the final comparison for the individual's working efficiency under this or that condition is usually made on the basis of an 'arbitrary' combination score. It is a question, therefore, if much of critical value would commonly be sacrificed by having the apparatus so arranged that it will automatically combine the error and time scores of all reactions into a total score for the test period. The possible gains of not having to measure the individual reactions, weight the errors, compute averages and otherwise manipulate the data after the experiment, may offset the loss of opportunity for minute analysis.

There are circumstances when it would be valuable, if not indeed essential, to know the results immediately following the test or even to watch them accumulate and sample them by short periods during the test. Dunlap (8), in outlining the practical requirements to be met in testing the resistance of pilots to increasing oxygen deficiency, found that it was necessary to have a single, comparatively brief test, continuous in nature but not in itself fatiguing, and which revealed the results immediately. There were special limitations by reason that the subject must at the same time be connected to a rebreathing apparatus but he concluded that the "final composite reason for using a clinical method (watching the reactions and coördinations of the subject rather than measuring them) comes from the need for rapid work. Graphic methods might be employed but would largely hinder the expedition of the work on account of the time and labor needed for their interpretation." Dunlap assembled on a rigid and especially convenient table a group of stimulus lamps which had to be reacted to when each one lighted by touching a stylus to a corresponding target. When the center of the target was touched a check lamp flashed indicating that the reaction had been correct and within a certain time interval. If the periphery of the target was touched an error lamp flashed. The reactor was to give his first and prompt attention to responding to the stimulus lamps. Two other things were also to be watched and roughly adjusted: the reading on an ammeter and the speed of a

motor. These required some visual and auditory attention respectively. The psychologist, sitting near and directly in front of the reactor, watched his ability to control and keep up with the three tasks and, as the oxygen decreased, secured a progressive clinical impression of the reactor's efficiency at different levels without having any of the tasks provide a graphic or quantitative record.

It was the notion of developing some quantitative test which would be suitable for studying progressive asphyxiation as well as the desire to have a continuous reaction apparatus adapted for the measurement of a subject's efficiency under different conditions of nutrition, drugs, muscular work and fatigue which is responsible for the present development. The following conditions are desirable of combination in such a testing apparatus: (1) The result of a reactor's performance to be immediately available both during and at the close of the test, and this without any further measurement or computation; (2) the result to be a logical combination of the quickness and accuracy of the performance; (3) the apparatus to give an integrated value not only for the reaction time and reaction errors but also for the adequacy of the coördinated movements which normally follow a reaction, and for which the reaction is only the natural beginning; (4) the task to be a continuous one, fairly uniform in difficulty from minute to minute and yet so varied as to require the constant watching of the one being tested; (5) the amount of muscular work required of the subject to be relatively small and to admit of a sitting posture and not to be particularly fatiguing. The muscular coördination involved to be simple and logical in connection with the end to be attained; to be free from distraction, to necessitate quickness, accuracy, and judgment and place no upper limit on the possibility for improved performance; (6) the task in its time relations to be repeatable for standard tests on the same individual or different individuals and to be applicable to children and adults of varying grades of intelligence; and (7) the apparatus to be fairly independent of any laboratory condition, thus making it usable in all sorts of surroundings

and capable of combination with other physiological or psychological measurements.

Description of the Pursuitmeter

(*a*) *The General Scheme*[1]

The task selected for testing purposes is that of continuously endeavoring to maintain the indicator of a wattmeter at a central zero position on its scale, by compensating with a variable resistance in one electrical circuit, changes in the amperage which are automatically induced in a second circuit through the action of an inductor device beyond the control of the subject. The arrangement is a combination of commercial electrical instruments adapted to the purpose by certain changes, principally in the winding of the field coils. The general wiring diagram is shown in Fig. 1. *A* is a wattmeter of horizontal edgewise type and zero center scale. This is viewed by the reactor and might be termed the stimulator. *B* and *C* are two test meters for integrating the errors of compensation, *B* accumulating those errors which the reactor allows to occur on the left-hand side of the zero position of *A; C* accumulating those errors on the right-hand side of the zero position. *D* is a curve drawing watt-

[1] For helpful suggestions in the early phase of planning, I am indebted to Dr. L. T. Troland. When spoken to concerning an electrical equipment for such purpose, he suggested the possible modification of a Wheatstone bridge employing an integrating meter in place of the telephone and requiring a subject to compensate with a variable resistance in one arm of the bridge variations which were automatically produced in the other. What has finally evolved is clearly related to that schematic idea.

To the kind coöperation of Mr. W. B. St. Clair, superintendent of the Standardizing Laboratory, General Electric Company, Lynn, Mass., is due the credit of providing a practical way by which common electrical instruments, all of which are produced by that company, could be so modified and combined as to attain the result which was sought. The willingness of Mr. A. L. Ellis, Mr. St. Clair and his assistant Mr. S. C. Hoare to advise and to have certain modifications of the electrical instruments made under their supervision is a coöperation, both personal and of the General Electric Company, which I cannot easily repay. I wish to acknowedge also the help of Mr. W. E. Collins, former mechanician at the Nutrition Laboratory and of my assistant, Mr. E. S. Mills, in the construction of the apparatus; the latter has especially aided me in collecting data for the Pursuitmeter test.

meter with zero center scale which draws in reduced amplitude the fluctuations of the needle of *A*.

In each of the four instruments, *A*, *B*, *C* and *D*, the field coils, which are, of course, stationary, were wound differentially, that is, with two wires in place of one, so that each instrument has four field binding posts. The number of turns and length of wire in both field circuits of an instrument were made the same and in the case of *B* and *C*, both instruments were made the same. When equal currents pass through the two windings, the two fields in an instrument oppose or buck each other and thus neutralize each other so

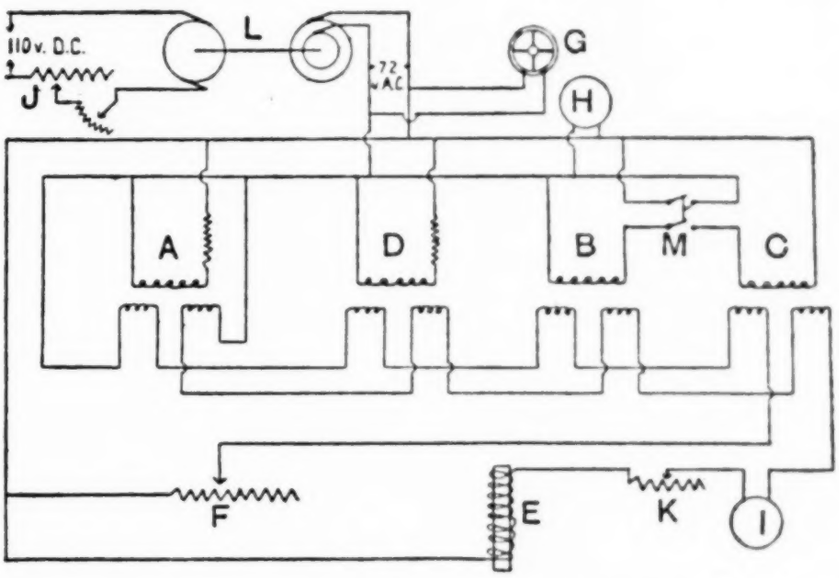

FIG. 1. General wiring diagram for the combination of electrical instruments which make up the Pursuitmeter. For lettering on figures, see text.

that no movement occurs in the armature of the instrument. The amperage in one circuit is disturbed by a combination of harmonic motions in the induction apparatus. *E* sets the task for the subject who seeks to compensate with the slide wire regulator, *F*. The disturber mechanism is operated by a motor, *G* with a worm gear reduction for driving the countershafts. *H* and *I* are voltmeter and ammeter respectively for standardizing the current in the disturbed circuit which may be adjusted by rheostats *J* and *K*, the former controlling the speed of the rotary converter *L*, which at the Nutrition

Laboratory was necessary to provide alternating current. As is well known, the moving systems of *A.C.* instruments and meters are very much lighter and more quick in their action than are those of the *D.C.* type. Hence this form was chosen as the more suitable for combination in such apparatus. The two wattmeters *A* and *D* are, of course, not dead beat. This is no special disadvantage. It only adds somewhat to the difficulty of the task.

The subject under test thus has not a number of discrete separate stimuli that are to be reacted to but a series of fluctuations which he is to parallel as nearly as possible. He watches the wattmeter, *A*, for his cue and does not know which way to move the regulator until the needle of *A* has started to leave the zero position, then having perceived the direction, he sees also something of the speed and governs his own compensation accordingly. The needle of *A* usually oscillates about its zero and the integrators *B* and *C* alternately turn up by small amounts and so accumulate the score. It is really a hare and hound game where you are to keep immediately at the rabbit's heel no matter what the direction of his jump or how quick or how far. There will always be loops where the two paths do not exactly coincide. These are the integrated areas which make up the score. They can never be entirely avoided but the object is to make them as small as possible.

The task outlined corresponds to that of holding voltage or steam pressure constant in a laboratory where instruments have to be standardized. It is somewhat like training a motion camera or a gun on a travelling object, steering a boat by the compass, trailing another automobile through crowded traffic and unfamiliar territory or driving on uneven car tracks. The same type of response is required in much industrial work. Much machinery necessitates not only a quick reaction but also a fairly definite coördinated movement following the reaction and this to be executed according to a fairly fixed pattern. There is thus reaction and pursuit movement for the purpose of compensating, directing, aiming, or otherwise tending these moving mechan-

isms. Undoubtedly it is possible to use industrial machines for measuring the individual's efficiency on the basis of his output, other conditions remaining suitable. Such mechanisms, however, are devised for manufacturing operations rather than to be used as psychological or physiological instruments in measuring the fluctuations of efficiency.

(*b*) *The Stimulus and Regulating Set*

To avoid distraction and for purposes of convenience in manipulating the subject and his surroundings, the stimulus wattmeter and the rheostat regulator are mounted together

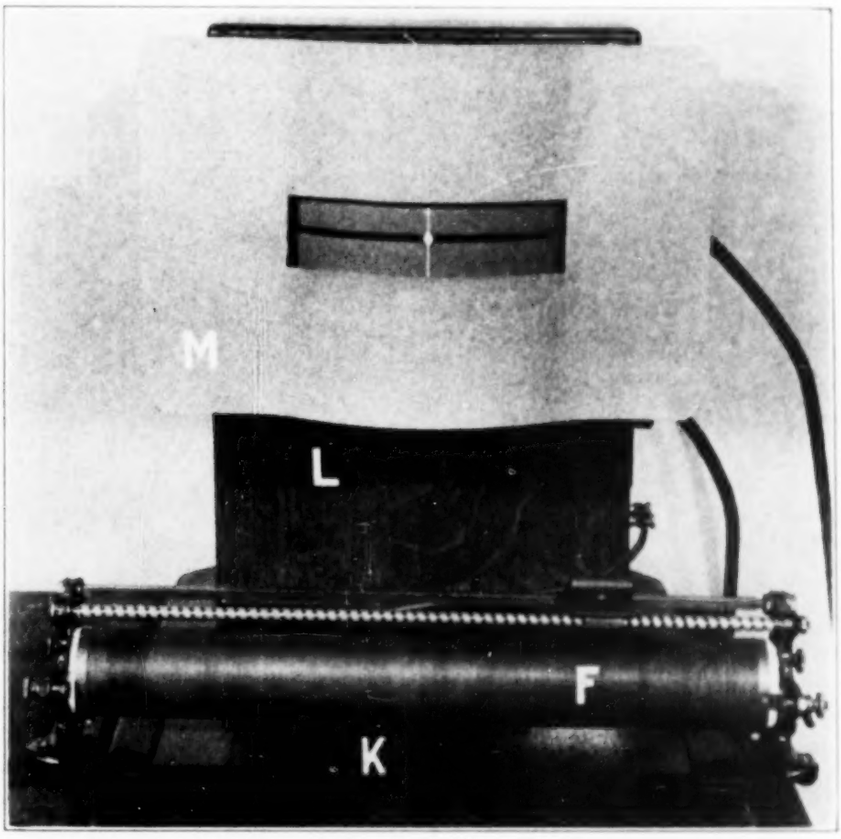

FIG. 2. Front view of the stimulus wattmeter and the regulator rheostat. By the manipulation of the rheostat a subject endeavors constantly to keep the wattmeter needle on the white zero line as illustrated.

in a unit which may be located according to desire in the same or another room from the other portion of the apparatus. The stimulus unit is shown in Figs. 2 and 3. On a suitable

platform *K*, 36 x 72 cm. in dimension, is securely fastened a small cabinet *L*, 40 cm. high. To this cabinet the wattmeter, *A*, is attached as it would be to a switchboard. The accompanying resistances for the wattmeter are placed inside the cabinet, arrangements having been made for cooling ventilation.

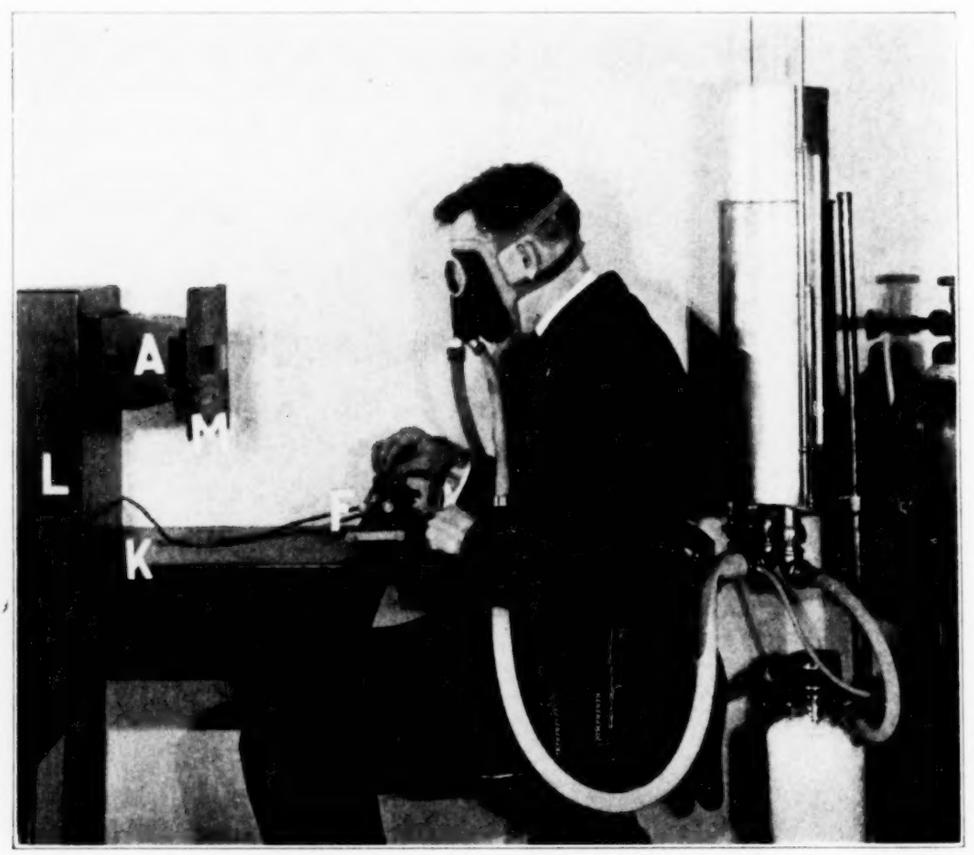

FIG. 3. Side view of the stimulus unit showing a subject being tested on the Pursuitmeter at the same time that his oxygen consumption is being measured on the "Benedict Portable" respiration apparatus.

Any task which requires continuous gazing at one object or area will cause vision to become at times somewhat blurred and after-image and contrast effects to be troublesome. This applies to the present apparatus as also to that of Seashore, McDougall and McComas. To make the visual conditions as satisfactory as possible, a screen *M*, 23 x 34 cm. in extent and faced with warm gray oatmeal paper was attached to

the front of the wattmeter and the scale of the wattmeter behind the curved glass was faced with the same material. This has proved to be a comfortable background upon which to observe the movements of the diamond-shaped needle which is white as in the figure. The white line which extends across the scale is the zero position on which the reactor tries to hold the needle, the ideal position being that shown in Fig. 2. No other marks are placed on the scale. The reactor is instructed to keep the white diamond as nearly as possible exactly in register with the white mark. Provided the scale of the wattmeter is not brilliantly illuminated, fixation troubles are but slight. There is nothing to prevent the subject moving his eyes or his head to relieve tension. However, he can not look away far, or for an appreciable time and keep up with his task.

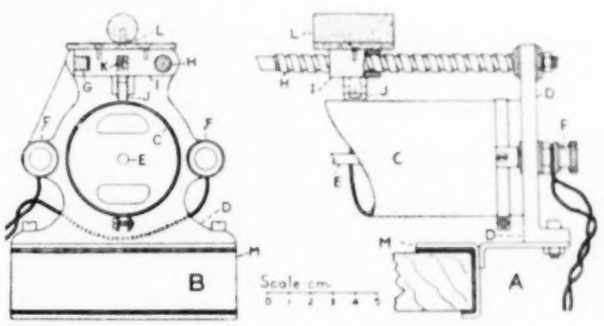

FIG. 4. Detail of the rheostat used as regulator, illustrating unusually rugged construction.

The compensation movement involves only the left or right hand according to the subject's preference and is direct, that is, he moves the rheostat slider in the direction that he wants the wattmeter needle to move. The coördination is a perfectly natural one. A six-year-old child can easily understand what is to be done and can do it after a fashion. The regulating rheostat is an important feature of such an apparatus. It should be of rugged construction, to avoid much wear and any loose parts or poor contacts and its slider should move with the least friction compatible with good contact on the resistance coil. These features were especially in mind in selecting and adapting the rheostat shown as *F*, Figs. 2 and

3, and in diagram, Fig. 4.[1] In this latter figure, *A* and *B* present side and end views respectively. The porcelain enameled tube *C*, is 16 inches long and wound with No. 25 Ideal resistance wire. The total resistance of the rheostat is about 400 ohms and the constant current capacity 1.2 amperes. The rugged construction may be seen from the heavy end pieces *DD*, the connecting rod *E*, the large binding posts, *FF*, and the two rods at the top, *G* and *H*. The former is square and the latter round and cut into a screw. The screw retains some oil and keeps the slide running smoothly. Upon these parallel rods *G* and *H* the slider, *I*, moves very freely and maintains a constant but very light pressure on the resistance wire. A shoe with a hard polished surface extends from the lower part of the slider and is kept in light contact by the action of a small coil spring, *K*. It is of prime importance that the slider shall not bind or stick or require anything but the slightest push of the hand to move it, otherwise the subject, who is trying to do careful compensating becomes exceedingly annoyed. The action is so easy that if the rheostat is tipped up vertically the slider will of its own weight move down to the bottom end. A large surface of fiber with a convenient portion, to be grasped in the fingers, is secured to the upper part of the slider. The rheostat is very conveniently and comfortably manipulated by the subject. Heating is never troublesome. In place of screwing or clamping the regulator to the baseboard which extends in front of the wattmeter, suitable guides, *M*, lined with cloth, have been secured to each end of the rheostat and these, passing one on either side of the baseboard serve not only to hold the rheostat firmly in place, but to make it adjustable as to its distance from the wattmeter. The subject in his preliminary adjustments can easily move the rheostat so as to best suit his own comfort.

(*c*) *The Integrating and Recording Instruments*

The two test meters for integrating the accuracy of compensation, together with the curve drawing meter, voltmeter,

[1] Made by H. E. Crane, Cypress St., Brookline, Mass.

ammeter and disturbing mechanism are built into a cabinet which is 80 cm. high by 70 cm. wide and 40 cm. deep. The upper part of this unit, showing the faces of the meters, may be seen in Fig. 5. The curve drawing meter is located on the top of the cabinet together with rheostat, *J*, which is in the 110 D.C. line and is for regulating the speed of the rotary converter and so adjusting the A.C. voltage shown in the voltmeter *H*. The push switch, *M*, for connecting the

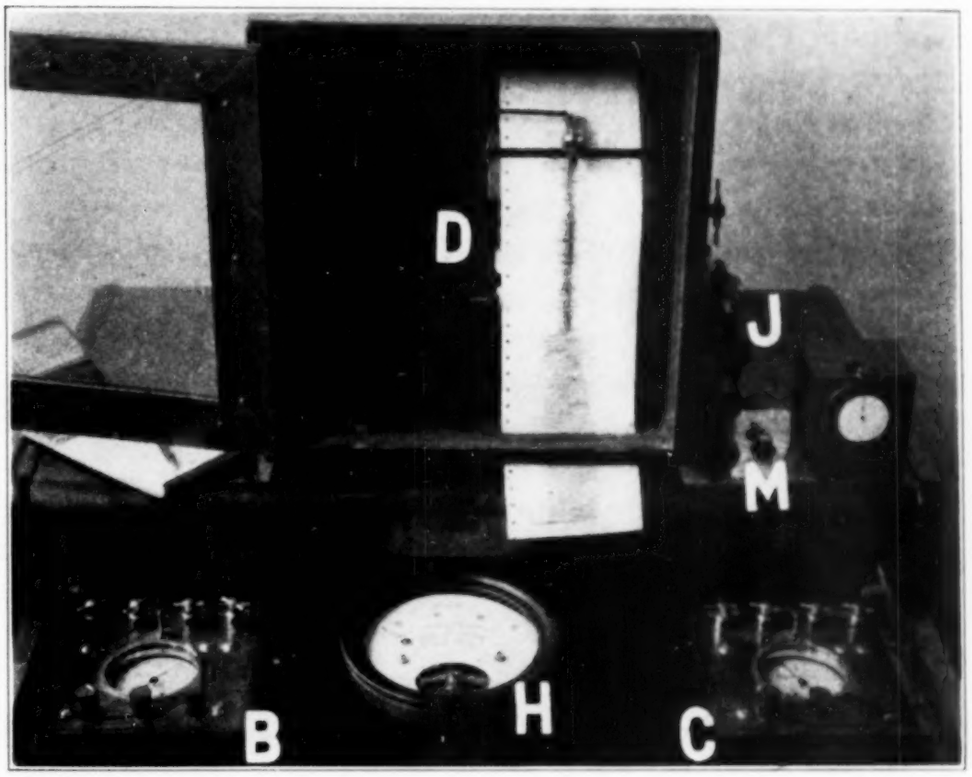

FIG. 5. Top view of the cabinet on which the integrating and recording instruments are mounted. This unit may be at any desired distance from the subject who is being tested.

potential sides of the integrating meters and so starting the test from zero position of the meters as well as stopping the test on the second is also on the top of the cabinet. The complete disturber mechanism is mounted inside the cabinet, the two integrating meters, *B* and *C*, are secured on the doors and the voltmeter is hinged from the top of the cabinet so as to come forward into a convenient position for observation by the experimenter. A glass plate lying across the top of

the two doors provides a convenient desk and makes possible the observation and reading of the meter as desired. Without disturbing any part of the circuit, the doors may be closed for convenience in keeping out the dust, or when moving the apparatus.

The curve drawing instrument, *D*, is the most expensive part of the combination and it is not absolutely essential. It could obviously be used for a curve drawing apparatus and also to take the place of the stimulus apparatus. However, it is more sluggish in its movements, more distracting in its operation and also the subject could see the graphic record or some part of it. Furthermore, it is hard to watch and adjust to the zero position the rather clumsy ink pen which is a siphon arrangement. A final consideration against using *D* as the stimulator is that its zero position is not very constant. The curve drawing meter is, however, quite useful in directly plotting the curve for the fluctuations caused by the disturber and the combination curve, made during the test, by the disturber and the reactor when the latter is trying to keep the current changes in the two circuits directly parallel. These records may be shown to the subject with a view to securing his better coöperation in further tests and it is thus unnecessary to make known his quantitative scores. This graphic record is not to be measured but indicates fairly well the consistency of the subject's work throughout the test period. Should he forget and releasing the rheostat slide, raise the reacting hand to his face, if it is necessary to cough or sneeze, or if he is distracted and looks about the room, the graphic record will show a loop in the curve which indicates clearly a lapse on the part of the subject. In standardizing the Pursuitmeter, one time with another, graphic records are useful and particularly in comparing the tasks when the movements of the induction apparatus are made simpler or more complex.

The integrating meters are known as portable test meters and are fitted with a zero set back arrangement. The dial is of white enamel, 6 cm. in diameter and divided into 100 divisions which are easily legible. The moving element is an

aluminum disc on a vertical shaft to which a large hand is attached. This hand indicates directly each revolution of the shaft which may be easily read to the 100th part of a revolution. There are two small hands with corresponding dials located within the large dial. One of these pointers makes a revolution for every 10 revolutions of the large hand, the other for 100 revolutions. The meters as modified were rated for one ampere on 72 volts. This was also the rating for the two wattmeters.

It is apparent from the general wiring diagram in Fig. 1 that a common test meter with the field coils wound differentially would turn in one direction when the regulated circuit was too low in its amperage and in the other direction when this circuit had an amperage above that of the disturbed circuit. Starting with the meters at zero if the combined errors were as great on one side as on the other, the final reading would still be zero. Some delicate and effective arrangement must be provided which will allow the meter to turn in only one direction and so cause it to accumulate the errors in one direction, while a second meter performs a like service for the errors on the other side. Such a device is shown diagramatically in Fig. 6. On the armature shaft *A*, which is directly connected to the large hand shown on the dial of the integrating meter, was mounted a small brass wheel, *B*, 12 mm. in diameter and 1 mm. thick. On the periphery of this wheel 300 teeth have been accurately cut. A light pawl, *C*, is arranged to engage with these in such a way that the shaft of the armature can turn in only one direction. This pawl is carefully mounted in end-stone, ring-stone sapphire jewels; it has but slight back-lash, and is kept in delicate contact with the wheel by a hair spring with adjustable tension arrangements at *D*. The pawl and its bearings are mounted in a heavy block, *E*, which is rigidly connected to the frame of the test meter. By this wheel and pawl arrangement the integrated errors on one side of the zero position are accumulated and the sum for the two meters provides the total score. These meters have a zeroizing mechanism which consists of the usual interacting cams upon

which pressure is brought by a small lever, *F*, and certain springs. The abuse of the delicately adjusted pawl, *C*, would be suicidal and is avoided by arranging a projection, L, from the plate, *M*, in such a position that when the plate is pushed forward to zeroize, the meter, *L*, engages with the counterweight of the pawl, *C*, and gently swings it out of contact with the wheel thus allowing free turning of the shaft, *A*, in either direction as necessitated by the position of cam, *J*, on the armature shaft. The spring, *N*, keeps *L* out of contact with *C* unless pressure is voluntarily exerted at *F*. The mechanism illustrated in Fig. 6, while rather delicate, in

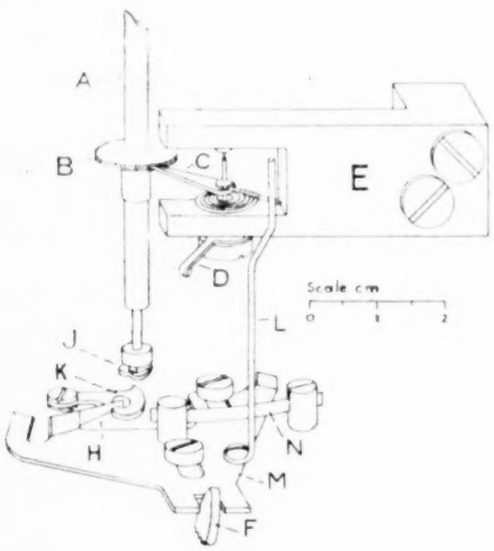

FIG. 6. Scheme whereby a pawl and fine toothed wheel arrangement makes it impossible for an integrating meter to turn in but one direction, hence it accumulates the errors.

reality remains in perfect and satisfactory operation for long periods at a time. As the scale on the dial of the test meter is graduated into 100 parts each such part corresponds to 3 teeth on the wheel, *B*. This degree of exactness in accumulating any small movements of the armature is wholly satisfactory as even a well practiced reactor will allow usual movements of from 2 to 8 divisions on the scale.

(d) The Disturber Mechanism

Of the many arrangements which could have been made to disturb one circuit and thus produce the task which will

occasion the compensation on the part of the reactor a variable inductance was chosen as being suitable. It is relatively permanent, easy of operation, nearly free from friction resistance, and relatively independent of any changes from wear. Originally the disturber was a combination of three induction units, *i.e.*, three coils with as many soft iron cores. These were moved up and down by independent counter shafts run at different rates. Each unit could be made to function in different degrees since between each two layers of the winding on a spool, a tap was taken out, which made it possible to short circuit sections of the winding, so that each independent induction unit could be made to add its particular component to the complex of fluctuation in that proportion which was desired. Practically that arrangement was more complex than necessary. There was, furthermore, positive disadvantage in it since with three cores to be moved at the same time in and out of their respective coils, one or two were most of the time sufficiently within the coils to introduce a considerable amount of reactance in the circuit with the result that the amperage was usually low and varied through quite small changes and only at rare intervals reached its higher value. The form of disturber mechanism that has proved successful is shown diagramatically in Fig. 7. On the bottom of the cabinet, *A*, the spool, *D*, of the induction apparatus is mounted in such a position that the core, *C*, can move freely in a vertical direction in and out of the winding. The winding is of enameled copper wire (.042 inch diameter), ten layers deep and comprises 1,415 turns with a total resistance of 5 ohms. A tap is brought out between each two layers. The spool, *E*, is of brass and is 17.5 cm. long, inside length. Both tube and collars of the spool are split along one side to avoid heating from eddy currents. The core, *F*, is of soft iron wire firmly bound together and is tapered from top to bottom, the longest part being 18 cm. in length. This core is fitted into a fiber tube, *G*, which is somewhat longer than the iron core and moves very easily in the spool. The core contains about 800 g. of iron and complete weighs less than 1 Kg. By a cord passing over pulleys at *H* and *I* the core is connected to a

counter weight, J, which weighs about 650 g. This serves to reduce the load on the driving motor, not shown in this diagram. The core, by the use of three countershafts, K, L, and M, is made to move vertically through a very complicated series of inharmonic motions or waves. Each countershaft is independent but all are driven by pulleys of different sizes on the common shaft, N, thus the speed of each counter-

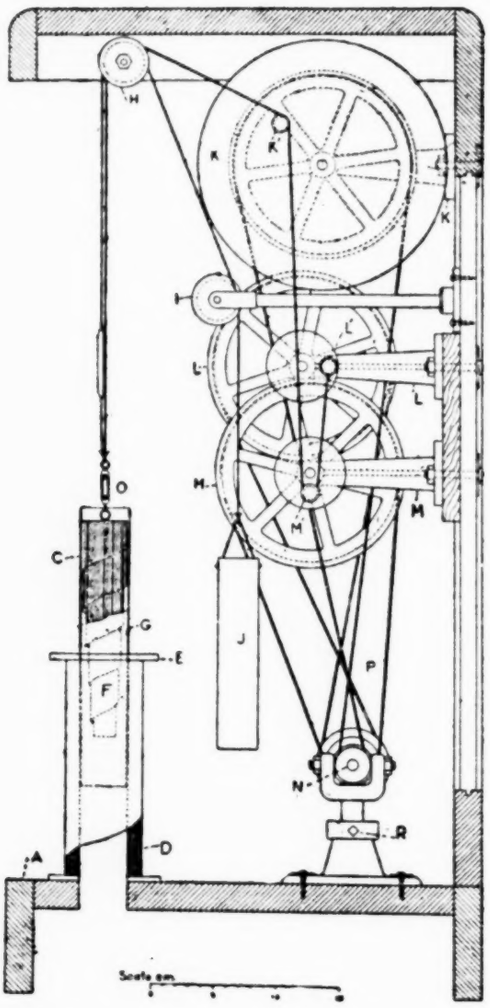

FIG. 7. Diagram of the disturber mechanism which is an induction apparatus the iron core of which is arranged to be carried through a complicated series of inharmonic motions.

shaft is different from that of the others as the driven pulleys above N are all 15 cm. in diameter. Each countershaft at its approximate end carries an eccentric which is at the same time a small pulley. (See K', L', and M'.) The cord through

which the movements of these eccentrics are to be transmitted to the core of the induction apparatus is fastened around L', passes under M', over K', and over a second pulley at H, not shown in the diagram, and thence is connected to the turn buckle, O, which supports the core and allows for suitable adjustment so that when at its lowest point it will just correspond with the winding. The three eccentric pulleys, K', L', and M', as commonly used (of course, they can be otherwise located) cause the core to move vertically 95, 40, and 57 mm. respectively, a total of 192 mm. The three belts, P, which transmit the power to the three countershafts are quite positive in their drive. The speed is not rapid and the load is relatively small. The shaft hanger, N, is adjustable at R, so that a certain range of tightening may be provided. However, a small amount of slipping of the belts adds to the complexity of the current variations which the subject has to compensate and is of no special disadvantage.[1]

Manipulation and Characteristics of the Pursuitmeter

The arrangement of three eccentrics just described was the form of disturber arrived at empirically. Preliminary trials were made with a simple wave form caused by periodically moving the core of one induction apparatus, using only one eccentric, K', and giving it sufficiently wide amplitude to produce the total movement of the core. Such a wave form of simple harmonic character can be seen in Fig. 8, A, which is a tracing from the curve drawing wattmeter. Using a wave form of this character with a slow period, an efficient subject can almost succeed in perfect compensation. When the period is made more rapid he will not succeed in keeping the needle at zero every instant. However, the task is so uniform as to be monotonous and does not challenge his effort sufficiently. If three eccentrics as described above are used and these given rotation rates such as to cause their combination to result in a non-periodic series, a wave form

[1] It is recognized that it would be rather difficult to make a second disturber that would have exactly the same characteristics as this one.

something like Fig. 8, *B*, is produced. This series of fluctuations made entirely by the disturber has maximal and minimal amperages of 1.5 and 0.4 respectively. The amplitude of the largest deflections on the stimulus wattmeter, *A*, in Figs. 1, 2, and 3, are 40 to 42 mm. both right and left of the zero position. The curve drawing wattmeter plots these fluctuations just half size, hence in Fig. 8, the vertical lines of these sample records are 2 cm. apart.

From the plotted wave form of the curve drawing apparatus, the pattern for the task which has been used as standard requires approximately eight minutes to repeat itself. This agrees with what should be found since the

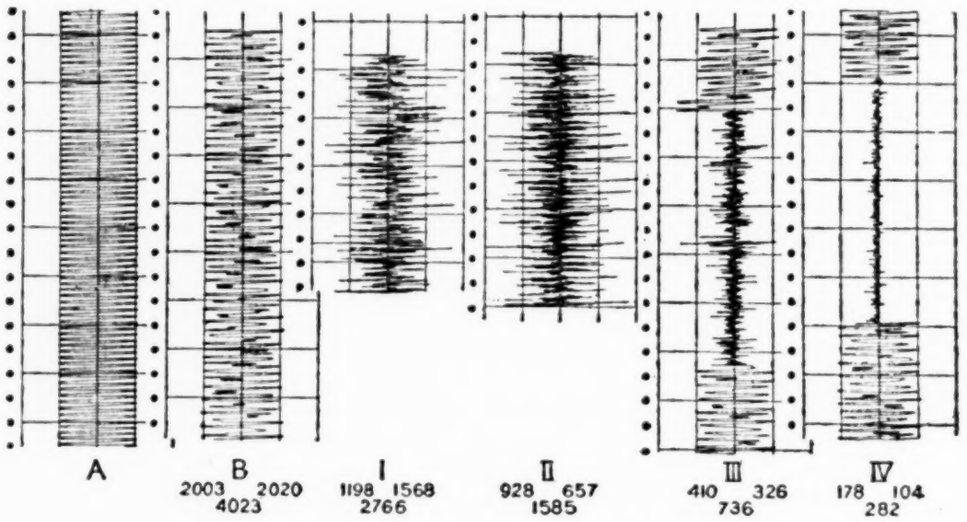

FIG. 8. Sample records made on the Pursuitmeter.

rotation speeds of the eccentrics, *K'*, *L'*, and *M'* are about 8.72, 4.03 and 5.40 seconds each which will divide nearly evenly into 480 seconds. The clock drives the paper for the curve drawing meter at the rate of one inch per minute but the periodicity of its escapement and small inaccuracies in the feed of the paper naturally change somewhat the curve which is plotted so that it seems never actually quite to repeat itself.

It is well within possibility that some subject should practically memorize the series of fluctuations if he had simply to watch them succeed each other. At least, it could be done if the subject set himself to it. It must be remembered,

however, that by his manipulation of the regulator rheostat in compensating the fluctuations, he disturbs the whole series so far as the curve drawing wattmeter and stimulus wattmeter are concerned. Therefore, by the position of the stimulus needle in relation to its previous movements, he cannot anticipate what it is going to do next especially in reference to speed and amplitude of movement. He may anticipate that it will not move any further in a certain direction than the position it has taken judged by the position of the slider on the rheostat. There is thus definitely, the possibility of a kinesthetic memory since the hand in moving the regulator must go through a series of lateral movements which closely resemble and are about of the same amplitude as the series made by the core of the induction coil, provided that compensation is about adequate. The amplitude of the hand movements will vary from 4 or 5 mm. up to 19 cm. There are probably some subjects who, after long practise, will pay some attention to this kinesthetic imagery but it is much easier and more accurate to watch the deflections of the needle rather than to trust to this memory, and the latter will usually play but small rôle.

The stimulus needle starts and stops about 20 times a minute. In a large majority of cases, it starts to move in the opposite direction from which it has been moving. This the subject soon learns. However, he must guard against too great an anticipation, since occasionally it stops and continues again to move in the same direction or moves but slightly the opposite way. When it starts, its speed and amplitude of movements are two factors which he can hardly judge, but must wait for and meet as best he can at the instant. Speaking generally, the subject is required to react about every three seconds and in the interval between reactions to compensate a moving system as adequately as possible. The more successful subjects make a rather steady, smooth movement with the rheostat slider, jerky extreme movements cause added deflections due to the period of the instrument and confuse to some extent. If the needle is allowed to escape far either side of the zero position, recognition of the

fact may cause something of a block in the reactor's work but is probably not quite such a disturbance as reaction errors with some other types of apparatus, since here it is a matter of degree rather than seeming to be definitely wrong unless the slider has been pushed in just the wrong direction and through a large amplitude. In this connection there is one feature against which the experimenter must caution his subjects. When the needle is quiet at a position that is fairly close to the zero line, some reactors let it rest and wait to see what is to happen next. Of course, the score tells the story and the plotted curve will show the larger errors, but the subject must be encouraged to keep actively at the job all the time he is being tested.

Certain very intelligent subjects, realizing that the integrating meters as well as the wattmeters, even though all A.C. instruments, have latency, have tried to beat the game by causing the needle to oscillate constantly across the zero line. The score has always been larger, *i.e.*, poorer, by this mode of compensation. While it would be desirable to have the armatures of these instruments move with the quickness and aperiodic characteristics of a string galvanometer, it is, of course, impossible and happily unnecessary. In adapting the instruments attention was given to making such changes as would reduce latency and over-shooting and since these factors are relatively constant they offer no special handicap to using the Pursuitmeter for comparative measurements, the purpose for which it was designed.

Another criticism may be raised which applies to the rheostat used as regulator. If a pointer is attached to the slider and a graphic tracing made of its movements while a skilled subject compensates a standard series of deflections as shown in Fig. 8, *B*, it will be found that from a neutral position the slider must travel much farther to the left than to the right. In fact from the position at which the slider remained constant during the time the tracing *B* was made 3.5 cm. of movement to the right will compensate the largest deflections to the left, while 15 cm. on the left will be required to balance the complementary deflections in the opposite

direction. Such a rheostat is a linear arrangement and the electrical resistance represented by 1 cm. of its length is effective in changing the amperage of the circuit in proportion to the resistance already in the circuit. One could wish for strict proportionality in the size of the coördinated movements required by the test, practically subjects adjust themselves quickly to this discrepancy and their errors are approximately equal on each side. They have not to continually remind themselves that smaller movements are to be made on one side than on the other; each coördination is, so to say, felt out bit by bit without special regard to where or how far the slider is pushed.

Discussion of Results

Should a subject under test for a period of 5 min. allow a score to accumulate in each meter of 300 points, *i.e.*, three revolutions of the large hand, this would be substantially equivalent to his having allowed the needle to be five millimeters off zero for as much as 2 min. on either side of the zero line. The score is stated in terms of revolutions of the integrating meters rather than in terms of watthours or coulombs, since the integrating instruments are not measuring strictly the amperage which passes through them but only a function of the difference between the amperage of the two fields. Various arrangements of other instruments were tried in combination with the Pursuitmeter to secure a basis for giving the score in terms of electrical units. These arrangements seemed to add only complications and not to make the result more intelligible or trustworthy. It is reasonable to compare the score made by a reactor against that shown when the apparatus itself is operating without any intelligent direction. The slider of the regulator may be placed at such a position that the deflections are of equal amplitude on either side the zero line; with a maximum in the disturbed circuit of 1.5 amps. from 72 volts after a five minute continuous run, each integrating meter will show a score of very nearly twenty complete revolutions, *i.e.*, 2,000 points; the total score for both left and right will be 4,000.

Referring again to Fig. 8, *B*, a five minute portion of this tracing which was taken as a test like the one described, and is the standard check of the Pursuitmeter's proper working condition, shows a score on the left integrating meter of 2,003 and on the right 2,020, total 4,023. Record No. 1, Fig. 8, was made by a girl eight years old. She had never before seen the apparatus and, until just prior to the test, knew nothing of what she had to do. The graphic record indicates rather slow movements and that at times for several seconds the needle was not made to cross the zero line. Her score is 1,198 for the left hand side, 1,568 for the right, a total of 2,766, which as compared with the 4,023, shows that some intelligent compensation was being exercised. She may be said to have compensated to about the extent of 30 per cent. Record No. 2 is the first trial of a young physician who also had never seen or heard of the apparatus before. After a practise of less than a minute, he made the score 928 left, 657 right, a total 1,585. This is about 40 per cent. of the uncompensated score. He therefore compensated to the extent of about 60 per cent. Record No. 3 was by an assistant who had had considerable practise with the apparatus throughout the period of its development and understood very well its mechanical and electrical features. His total score of 736 is only a little over 18 per cent. of the unbalanced score. About midway in this record, there is a large deflection seen on either side the zero position, coincident with which the subject coughed. Record No. 4 is by the most skillful subject who thus far has been tested. It indicates quick reaction and that each compensation is a very smooth and controlled movement, not just the pushing of the slider to the opposite end of the rheostat. The total score of 282 represents that compensation has been adequate to the extent of about 93 per cent. of the total value. If a subject is approaching too near a zero score, the reasonable thing to do is to increase the complexity or speed of the disturber fluctuations. It is desirable, however, for long periods of experimentation on the same individual and where different individuals are to be compared in reference to the in-

fluence of some outside factor, if the task can be made difficult enough to start with so that it will satisfy all requirements throughout the whole series without at the same time being so hard as to wholly discourage the unpracticed and less efficient subjects.

As illustrative scores for average adult performance on the Pursuitmeter some data are given in Table 1. These records were taken on several members of the laboratory staff, each person making five successive 5 min. trials per day. The average score for each subject on each day is shown in the table. All of these subjects were entirely new at the task. *Bw* and *Dw* were women and demonstrate marked and very consistent improvement. The men *C* and *E* also improved

TABLE I

AVERAGE ADULT PERFORMANCE ON THE PURSUITMETER. FIVE SUCCESSIVE 5 MIN. TRIALS WERE MADE BY EACH SUBJECT ON EACH DAY. THE VALUES ENTERED ARE THE AVERAGES. *Bw* AND *Dw* WERE WOMEN

Subject	Successive Days of Practice				
	1	2	3	4	5
Bw	1,330	945	872	774	772
C	1,020	1,061	839	919	812
Dw	1,621	1,372	1,241	1,094	1,073
E	1,714	1,426	1,468	1,677	1,392
F	2,423	1,759	1,559	1,412	1,276
G	2,501	2,055	1,656	1,429	1,378
Av.	1,768	1,436	1,272	1,217	1,117

by practise, as indeed any reactor should do, but they both were quite erratic and did poorly on the fourth day. Subjects *F* and *G* at the beginning did little better than the 8-year-old girl, but percentage-wise they improved more than the others excepting *Bw*. In general adults make a score of about 1,800 on the very first trial. The average for the group shows 1,768 for the first day of five trials and some improvement for each day thereafter, with an average score of 1,117 on the fifth day, *i.e.*, after twenty-five 5-min. periods of practice. In the case of four subjects, *A*, *C*, *Dw* and *G*, the results for all the practice periods have been plotted individu-

ally in Fig. 9. The scores are quite regular in every case. *A* made but little change during these 25 trials having had some earlier practice. The others show consistent practice effects. Between trials Nos. 25 and 26 there was a break of one month's vacation. *Dw* shows up definitely poorer during this latter period which correlates with her poorer physical condition experienced then. The other three continue their improvement in the test.

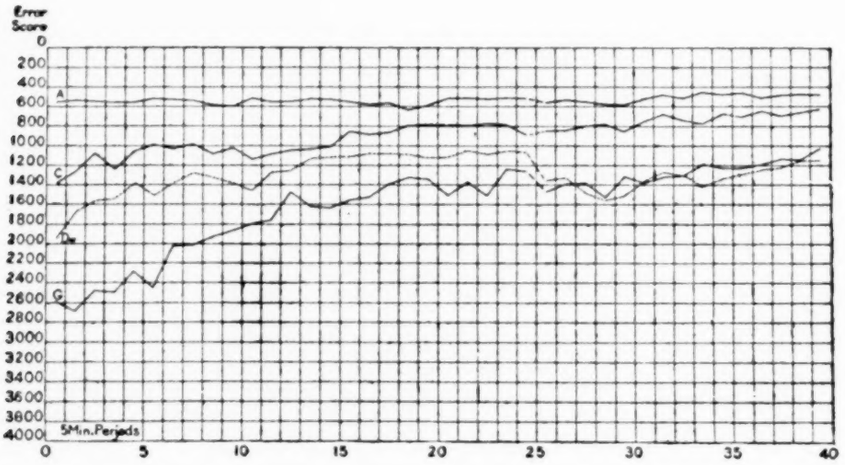

FIG. 9. Individual practice curves indicating the acquisition of skill in the Pursuitmeter Test. Between trials No. 25 and 26 a vacation period of one month intervened.

The Pursuitmeter has proved a convenient and sensitive test of neuro-muscular efficiency. It is, among other uses, quite applicable to the investigation of problems of nutrition when some superimposed factor is brought to bear on the human organism. Such use of the measurement may be illustrated by a bit of alcohol data from a research now in progress. The data are not given here as a contribution to alcohol literature; being on one reactor they must not be generalized. The presentation here is only to show illustrative data obtained with the apparatus. Following a light lunch the subject went through a series of measurements, 8 tests in all, which included the Pursuitmeter test. The series was repeated and after the second period he drank 1 liter of water or 1 liter of water in which 27.5 grams of ethyl alcohol had been diluted. The quantity of liquid and temperature were

not varied. Fifteen minutes were quite sufficient for drinking the liquid, after which the series of measurements were repeated three more times, *i.e.*, periods 3, 4, and 5 of the day. Table II, which is typical of several which might be given,

TABLE II

DATA ILLUSTRATING THE CONVENIENCE AND SENSITIVITY OF THE PURSUITMETER TEST AS A MEASURE OF CHANGES IN NEURO-MUSCULAR EFFICIENCY AS PRODUCED BY A NUTRITIONAL FACTOR

Date	Successive Half-hour Periods					
	1	2	Drink	3	4	5
1919						
Nov. 5	460	436	1 liter water	456	450	477
Nov. 8	407	370	" "	395	386	381
Nov. 19	365	357	" "	339	335	399
Nov. 21	426	378	" "	342	362	382
Nov. 22	354	341	" "	346	331	317
Av.	402	376		376	373	391
	389			−13	−16	+2
Nov. 6	436	424	1 liter 2.75% alc.	447	449	467
Nov. 7	417	378	" "	380	442	446
Nov. 10	390	374	" "	393	419	424
Nov. 17	398	387	" "	423	428	445
Nov. 18	367	320	" "	416	398	417
Av.	402	377		412	427	440
	389			+23	+38	+51
				36	54	49
				389	389	389
Av. loss, 11.9 per cent.				9.3	13.9	12.6

shows data for five normal days and for five days on which alcohol was used. The values entered are the sum of the two meter readings for a 5 min. test period. The average score for the first periods of normal days is 402; the average score for the first periods of the five alcohol days is 402. Likewise the averages for the second periods for the two groups of days are 376 and 377 respectively. It is simply a matter of chance that these preliminary values are so identical. It must be recalled in interpreting these data that the smaller scores represent the better efficiency. Following the drinking of the water the subject was able to do just about the same as he

did at the second period, or if we average the first and second periods to get his preliminary performance, we find that in general, he did better by 13, 16, and poorer by 2 points in periods 3, 4, and 5 after the water. On the other hand, following the alcohol, the compensation was poorer on the average then the subject had done in the preliminary periods. There is only one instance (third period, November 7, 380 as compared to 417) when the subject did as well or better after the alcohol than he had done in the poorer of his preliminary periods. The average decrements for the alcohol days as against the preliminary score, 389, are 23, 38, and 51. The differences between these and the performance when only water was taken show for periods 3, 4, and 5 losses of 36, 54, and 49 points on the basis of 389, thus corresponding to 9.3, 13.9, and 12.6 per cent., with an average loss for the three periods of about 12 per cent. The measurements represented by periods 3, 4, and 5 came approximately 15, 45, and 75 minutes after the ingestion of the alcohol. This table was chosen for illustration because practice was still producing considerable change in the scores. Although there was improvement in the subject's scores between November 5 and 22, still the data within any one day are uniformly consistent and each succeeding pair of days, if taken separately, show practically the same contrast in efficiency when measured by this continuous reaction-coördination apparatus.

Summary

1. For detecting the influence of superimposed nutritional factors, fatigue, industrial conditions and the like, it is urged that not only the reactions but the eye-hand coördinations that naturally follow reactions should be measured.

2. An apparatus called a Pursuitmeter is described in detail. It is an arrangement of common electrical instruments which tests the subject's ability to balance two electrical circuits. The task is continuous and requires constant attention calling for both quickness and accuracy. The amplitude and duration of all errors are integrated electrically and accumulated by two meters which may be read directly during or at the end of the test.

3. The measurement of children and adults may be directly compared. It is shown that practice results in quite regular improvement and that the apparatus provides a very convenient and at the same time sensitive indicator for neuro-muscular efficiency.

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FURTHER TECHNIQUE FOR INSPIRATION–EXPIRATION RATIOS

BY HAROLD E. BURTT

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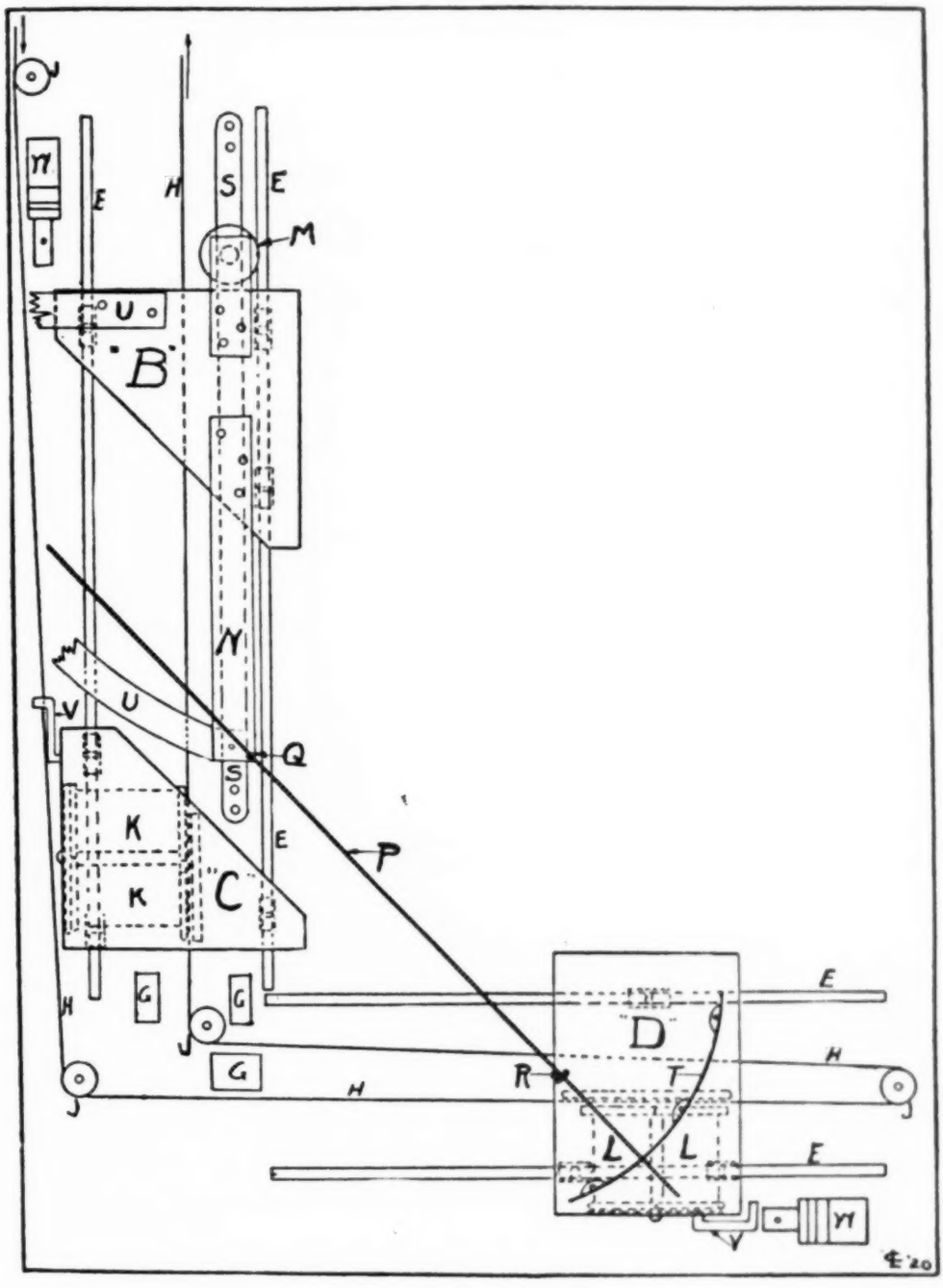
A device has been previously described for closing one electric circuit during inspiration and another circuit during expiration.[1] It consisted essentially of a one–way contact attached to a tambour operated by the usual pneumograph. This contact was in series with the magnet of a double relay and the two relay circuits could be used to trace two time lines (interrupted 5 or 10 times a second) on a kymograph or to operate two electric counters each of which recorded 5 or 10 units a second while the circuit through it was closed. In either instance the process of obtaining the I/E (inspiration-expiration) ratio was tedious. It was necessary to measure time lines or count them if they were in series with an interrupter, or to subtract the successive readings of the counters. The ratio was then computed on a slide-rule for each breath. The device described below is connected to the double relay, supplanting the kymograph or counters, and at the conclusion of each breath indicates on a scale the I/E ratio for that breath. These figures can be recorded during the experiment.

The apparatus is based on the fact that the ratio between the legs of a right triangle is the cotangent of one of the acute angles. If two members move from the right angle along the legs at constant speed one during inspiration and the other during expiration and if a straight line connects them at the end of a breath, the I/E ratio can be read in terms of the angle thus formed.

Three light wooden cars B, C, and D (see figure) each having three wheels move on two tracks E situated at right angles. The tracks are in the same plane but the whole apparatus tilted slightly so that gravity brings C and D

[1] Burtt, H. E., 'A Pneumograph for Inspiration Expiration Ratios,' *Psychological Bulletin*, 1918, *15*, 325–328.

against the stops *G* and brings *B* against *C*. The stops and the contiguous edges of *B* and *C* are padded to reduce the noise. An endless belt *H* (two lengths of ordinary string



twisted together) is driven at practically constant speed by a motor and worm reducer over the pulleys *J*. Cars *C* and *D* have electromagnets *K* and *L* mounted beneath them with

armatures suspended from the under sides of the cars. The endless belt passes between the armatures and the poles of the magnets in such a way that if the belt is moving in the direction of the arrow the sections of it passing over the poles of the magnets are moving in a direction away from the stops toward the outermost ends of the tracks. When the current passes through the magnets the armatures clamp the cars to the belt and they move in the corresponding direction. A magnet *M* is mounted vertically on the front of *B* with the bottom end of its core very close to a strip of iron *S* of adjustable height and extending under the entire course of *M*.

Car *B* is pushed along by *C*. It carries a brass member *N* which projects over *C* when the two cars are together. A very light lever *P* is pivoted on this brass member at *Q* and passes through a guide *R* projecting from the top of Car *D*. This car also carries a curved rest *T* for this end of the lever which is the heavier.

When the apparatus is at rest *Q* and *R* are as close together as possible (theoretically they should coincide but a slight amount of play is mechanically necessary) with the lever parallell to the *BC* track. The pneumograph previously described operates the magnet of a double relay. During inspiration the current from the relay passes through *K* and the two cars *B* and *C* and hence the pivot *Q* travel at constant speed up the incline with the lever *P* remaining in the same direction but lengthening its portion between *Q* and *R* directly in proportion to the length of the inspiration. During the following expiration the current is broken through *K* but is made by the other pole of the relay through *L* and *M* in parallel. Car *B* is immediately clamped to the rail *S*, while *D* and hence the guide *R* move at right angles to the direction taken by *Q*. The distance traversed by *R* is directly proportioned to the expiration time. The lever forms a gradually lengthening hypotenuse of a triangle and the cotangent of the angle formed between the lever and a line through *Q* parallel to the track is a direct index of the inspiration expiration ratio. A cardboard scale mounted on *B* (only a portion

of the frame *U* supporting the scale is shown) is traversed by the shorter arm of the lever and graduated to read directly the cotangent of the angle.

To avoid injury to the apparatus by a very long breath the cars *C* and *D* carry projecting arms *V* which will, as the car approaches the end of the track, strike the circuit breakers *W*. These consist each of a piece of brass hung vertically from a hinge and resting under gravity against a spring brass contact. These breakers are in series with the respective magnets. The arms *V* push the swinging members away from the contacts thus breaking the magnet circuits, releasing the armatures and allowing the belt to slip through without pulling the cars farther. If a breath is unusually long and either circuit breaker operates the car can be seen to vibrate back and forth slightly in its position near the end of the track and that breath can be omitted. During expiration the car *C* moves back to the zero position under the influence of gravity and is ready for the next inspiration, but car *B* remains in its position until the ratio is indicated by the lever. At the end of expiration *B* and *D* start back and the reading must be caught at that moment. *C* starts again with the following inspiration (it has ample time to return during the preceding expiration). *C* meets *B* coming back and carries it along until the end of inspiration and *D* has meanwhile returned to the starting point. The use of the additional car *B* obviates the necessity of having two identical pieces of apparatus working alternately.

The present model of the apparatus is about 14 x 18 inches outside dimensions. With this size the scale can be read easily to 0.1 and for smaller ratios to 0.05. With a little practice one can catch the reading at its maximum point as the lever starts to swing back to the initial position. The speed of the belt may be adjusted for slow or rapid breathing by attaching it to a different portion of the cone reducer connected with the worm. The magnets are wound with No. 36 wire and each run in series with a 25-watt lamp.

The time saved by the device is considerable. In some experiments now in progress, there is a clear saving of three

hours in reading kymograph records for every hour of experimentation. The reliability of the results is also increased because the experimenter can note any unusual conditions such as coughing or premature speaking and omit those breaths from the record. Needless to say the technique is applicable only where the entire interest is in the I/E ratio and not in the length or amplitude of the breaths.

COMPLEX SIGNS IN DIAGNOSTIC FREE ASSOCIATION[1]

BY CLARK L. HULL AND L. S. LUGOFF

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Introduction

In 1904 Jung, Riklin, Wehrlin and other members of the Bleuler-Freudian school of psychiatry, began publishing in the *Journal für Psychologie und Neurologie*, an extremely significant series of studies on free association as a means of diagnosis. Some of these studies are somewhat theoretical and *a priori* in character, but many of them are thoroughly scientific and quantitative in their nature. In them two things stand out: (1) Jung's classification and analysis of the kinds of responses given by various types of normal and pathological individuals and (2) his enunciation of various signs (Komplexmerkale) by which he believed emotional complexes to be indicated. It is with the latter aspect of the free association method that the present investigation is concerned.

Jung seems to have noticed these signs first as a result of general observation of the reactions of the patients in his clinic while giving the free association tests. He appears to have noted marked coincidences between certain types of reaction and the presence of emotional complexes as revealed chiefly by introspections obtained from the patients. These introspections were secured by a special technique now well known by the name of psychoanalysis. Unfortunately Jung was content for the most part to base his belief in the various signs merely upon such general observations. With an exception to be noted later, he made little attempt to secure any exact or objective evidence as to the truth of these important assumptions. Yet his statements seem to have

[1] This is the first of a series of Wisconsin studies in free association.

been accepted with little question by psychologists and to have found extensive application in practical diagnosis.[1]

The unsatisfactory state of this field in mental pathology is shown by the fact that there are innumerable points concerning complex signs upon which we have no decisive evidence whatever. Indeed many of the questions seem never to have been raised at all, despite their obvious clinical importance. For example, do *all* of the alleged indicators really indicate emotional complexes? And of those indicators which do, how strong are the strongest and which are the weakest? Does long reaction-time really deserve the prominence usually given it?[2] And what is the diagnostic status of extremely short reaction-time?[3] Moreover, if long reaction-times really indicate complexes, exactly how long must they be before doing so? Is the transition in potency from non-critical to critical times, gradual or abrupt? And how does diagnostic potency above the critical point, vary with further lengthening of the reaction-time? Or again, does the significance of reaction-time lie in its absolute or its relative length or in some kind of joint relation of the two?

Or we may consider a single detail like the alleged perseveration tendency of which Jung makes so much.[4] Does it really exist apart from accidental successions of long reaction-times, say, and if so how strong is it? Does it exist in the case of all the complex signs or only for some? Is it equally strong for all signs where it operates at all, or does it vary, say, according to their respective diagnostic strengths? How long and how far in the series does it persist, and is the curve of its diminution one of positive or of negative acceleration? May perseveration take place in terms of a complex sign other than that of the critical (initiating) reaction, and if so, relatively how strong are the various possible combinations of critical and post-critical signs? Do two or more

[1] Brill, A. A., 'Psychanalysis,' Philadelphia, 1917, p. 140 ff.

[2] Jung, C. G., *J. für Psychologie und Neurologie*, IX., p. 189; also Jones, Ernest, 'Papers on Psycho-Analysis,' New York, 1919, p. 406.

[3] Dooley, Lucile, 'A Study in Correlation of Normal Complexes by Means of the Association Method,' *Am. J. Psychol.*, 1916, XXVII., p. 132.

[4] Jung, *op. cit.*, p. 189.

complex signs appearing in a single critical reaction, tend to mutual inhibition or facilitation of their normal perseveration tendencies, and how does this action vary with different combinations of signs and diagnostic potencies? It was with a view to calling attention to numerous problems of a similar nature and to contributing some suggestions toward the solution of a few of them in so far as they apply to normal subjects, that the present investigation was undertaken.

The data consists of 10,000 free association reactions obtained from 100 subjects, 50 men and 50 women. The subjects came from the various middle and upper levels of population from the cities of Chicago, Duluth and Madison. All possessed a grammar school education, the majority had completed the high school and a few were attending the University of Wisconsin. The experiments were in all cases conducted in a quiet room free from distractions. The experimenter was the same throughout.

The instructions given the subject were as follows: "I am going through a list of words. After every word I say, I want you to respond with the first word that comes to your mind as fast as you can, and no matter what the word is. It is as if I say the word 'table,' and the first word that comes to your mind is 'chair,' you say 'chair.' Do you understand? We'll try one word to see if you have got the idea. I'll say the word and you say the first word that comes to your mind as fast as you can and no matter what it is. All ready now—'Snow!'" If the subject then understood what was wanted of him he was told, "Now we'll run through the list." If he did not understand, other practice words were given until he showed that he had a clear idea of what he was to do. It was seldom necessary to give more than one practice word. He was then given the 100 words of Jung's well-known association list in the order given on p. 116.[1] The time required for the reactions was measured by a fifth-second stop watch and

[1] Jung, C. G., 'The Association Method,' *Am. J. Psychol.*, XXI., 1910. The present list deviated slightly from that of Jung in a few places. The most of the infinitives of the original have been changed to gerunds as being under the circumstances more nearly the psychological equivalent in English of the German originals.

recorded as made. Various complex signs not shown by the verbal response word and the time, such as repeating the stimulus word, laughing, etc., were recorded by a convenient set of arbitrary signs.

After all the words had been reacted to, the subject was instructed as follows: "I am going through the list of words once more and I want you to try to give me the same words you gave me before. If you remember or think you remember, say it. If you don't, say 'No.' You can take as long a time as you want, to answer." Whenever any peculiar or unusual reaction was made, subject was quietly asked to explain it before proceeding with the experiment. At the conclusion, elaborate notes as to any peculiarities of the behavior of the subject were made on the back of the recording blank. Lastly each record was gone over while fresh in experimenter's memory, and scored with great care by means of a system of arbitrary signs. One arbitrary sign was placed opposite the stimulus word for each complex indicator found connected with that word.

The complex signs investigated in the present study are as follows:

1. Long reaction-time (over 13 fifths of a second).
2. Inability to make any response whatever.
3. Extremely short reaction-time.
4. Repetition of the stimulus word itself.
5. Assimilation (apparent misunderstanding) of the stimulus word.
6. Defective reproduction of original reaction at second presentation of the stimulus word.
7. Response with the same reaction word at two or more different stimulus words.
8. Strange or apparently senseless reactions.
9. Perseveration.

II.

The Relative Power of Various Words to Evoke Complex Signs

At the outset, it is a matter of some interest to know with as much precision as possible the characteristics of the series

of words used as stimuli. The list here employed is the result of years of careful trial by Jung and it is supposed to contain special properties.[1] Are some of the words very potent in revealing emotional complexes and the rest neutral, or is power widely and about equally distributed? Are powerful words placed in groups or at intervals or do they appear in the list according to chance? Are some words specially significant for one sex and others for the other sex, or are there no sex differences in this respect.

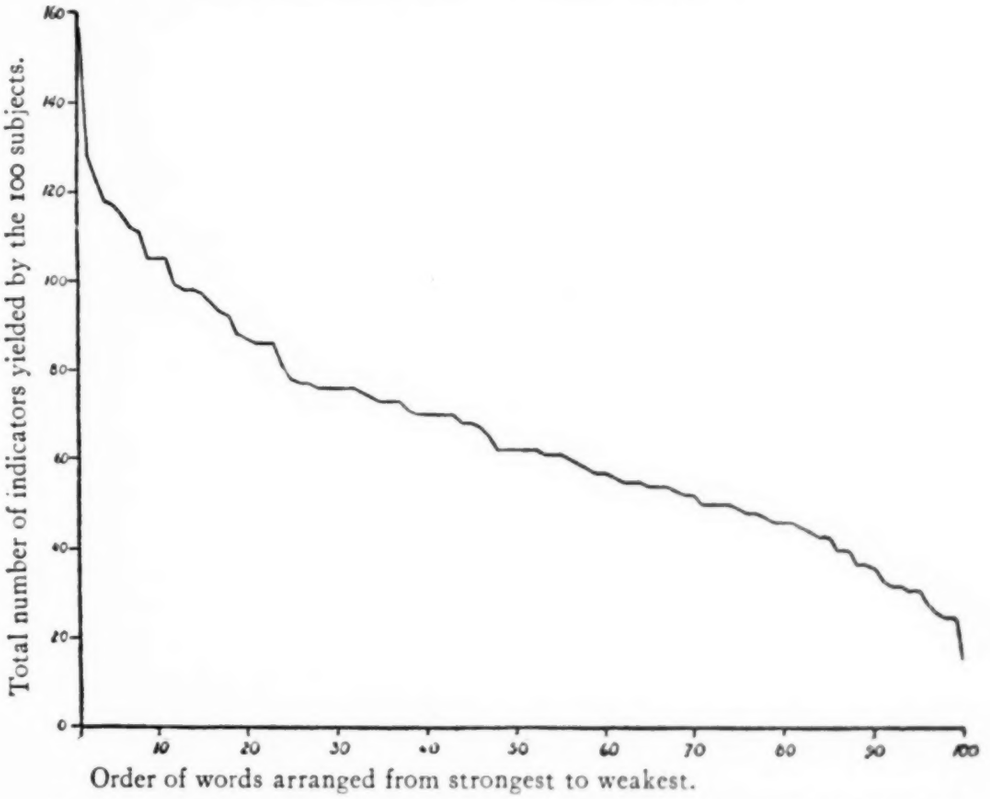


FIG. Showing the distribution of power of the respective words of Jung's list to evoke complex signs.

In an attempt to find at least an approximate answer to some of the above questions, it was assumed provisionally that all of the alleged complex signs here investigated really indicate emotional complexes; that all indicators are equally potent in this function; and that the greater the total number of indicators yielded by a particular word in the records of a large number of subjects, the more powerful that word is in revealing emotional complexes. The indicators were therefore tabulated by words separately for the fifty men and the

[1] Brill, *op. cit.*, p. 140.

TABLE I

SHOWING THE NUMBER OF COMPLEX SIGNS YIELDED BY THE 100 SUBJECTS FOR EACH OF THE WORDS OF THE JUNG LIST

	Men	Women	Both		Men	Women	Both
1. head	22	23	45	51. frog	23	27	50
2. green	34	36	70	52. to part	59	46	105
3. water	36	41	77	53. hunger	25	27	52
4. sing	34	26	60	54. white	36	40	76
5. dead	30	32	62	55. child	38	37	75
6. long	18	19	37	56. caring for	75	53	128
7. ship	34	23	57	57. pencil	17	20	37
8. pray	31	31	62	58. sad	38	38	76
9. window	26	24	50	59. plum	24	30	54
10. friendly	54	64	118	60. marry	41	54	95
11. cooking	31	24	55	61. house	25	18	43
12. ask	30	37	67	62. dear	47	50	97
13. cold	29	30	59	63. glass	32	42	74
14. stern	47	52	99	64. quarreling	40	37	77
15. dance	30	28	58	65. fur	15	25	40
16. village	19	13	32	66. big	23	26	49
17. lake	28	27	55	67. carrot	31	30	61
18. sick	23	29	52	68. painting	27	18	45
19. pride	66	49	115	69. parting	54	58	112
20. bake	34	40	74	70. old	20	28	48
21. ink	27	34	61	71. flower	32	36	68
22. angry	52	53	105	72. beating	57	54	111
23. needle	16	16	32	73. box	40	28	68
24. swim	39	42	81	74. wild	28	26	54
25. voyage	24	26	50	75. family	27	35	62
26. blue	40	46	86	76. wishing	32	38	70
27. lamp	22	22	44	77. cow	14	17	31
28. to sin	80	77	156	78. friend	46	52	98
29. bread	39	26	65	79. luck	30	32	62
30. rich	20	26	46	80. lie	37	36	73
31. tree	16	17	33	81. conduct	42	46	88
32. prick	41	46	87	82. narrow	13	23	36
33. pity	58	47	105	83. brother	15	11	26
34. yellow	49	43	92	84. fearing	55	62	117
35. mountain	16	12	28	85. stork	16	24	40
36. to die	37	36	73	86. false	43	43	86
37. salt	28	29	57	87. anxiety	45	33	78
38. new	23	24	47	88. kissing	30	41	71
39. custom	44	42	86	89. bride	24	19	43
40. supplicate	63	55	118	90. pure	27	26	53
41. money	22	26	48	91. door	26	24	50
42. foolish	29	33	62	92. choosing	30	46	76
43. pamphlet	26	29	55	93. hay	12	13	25
44. despise	37	19	56	94. contents	34	36	70
45. finger	13	12	25	95. ridicule	37	33	70
46. expensive	36	34	70	96. sleeping	20	11	31
47. bird	27	19	46	97. month	35	10	45
48. fall	27	49	76	98. nice	47	46	93
49. book	26	28	54	99. woman	35	26	61
50. unjust	41	32	73	100. abusing	50	48	98

fifty women, totaled, and these totals combined for the final determination of the potency of the individual words. These results appear in Table I.

A brief glance at this table shows that power of evoking complex indicators is very widely distributed. Not a single word in the list fails to show its quota of signs. That there is no break or even a considerable tendency to cleavage between strong and weak words is demonstrated very clearly by the curve of Fig. 1, which shows the relative strength of the 100 words arranged in the order of potency from the strongest to the weakest. Indeed the almost perfect ogive form of this curve shows that the frequency distribution of words in this respect is almost exactly Gaussian or according to pure chance. The interested reader may easily verify this by plotting a frequency polygon of the data in Table I.

As to the arrangements of the weak and strong words in groups or at intervals, relatively little can be discovered even by a careful inspection of Table I. Fortunately there is a method by which any given tendency to sequence of weak and strong words may be detected and its strength determined. For example, in Table I., of all the words which come immediately after strong words, 20 are themselves strong and 32 are weak; and of all words following directly after weak words, 32 are themselves strong and 15 are weak. Clearly weak words tend to follow strong words and strong words to follow weak. By a method to be described later (p. 125), the strength of this tendency to alternation may be determined with precision. In the above case it is $-.45$. This is about half way between a purely chance sequence and a perfectly uniform tendency to alternation of weak and strong. A similar computation for words following next but one, yields a coefficient of $+.25$. This is about a quarter of a tendency for both weak and strong words to be followed by one of their *own* kind, after an interval of one word.

In all, nine such coefficients were computed, determining the nature and the extent of the arrangement of the words for various distances following the respective weak and strong words of the list:

1st. following, − .45	4th. following, + .06	12th. following, + .14
2d. following, + .25	5th. following, − .41	25th. following, − .31
3d. following, − .31	6th. following, + .35	50th. following, + .29

The above figures show that Jung not only tried to have a weak word follow a strong one whenever a strong one appeared on the list, but the uniform alternation of plus and minus signs in the above table shows that the alternation was a definite program extending as far as 50 words distant. No doubt the coefficients would have been larger had it not been for the influence of the translation of the words from the German, and certain changes introduced into the list by the present writers. The distinctly smaller size of the plus coefficients is suggestive though its meaning is not quite clear.

The character of the words bearing the heaviest burden of complex signs next engages our attention. The Freudian literature leads us to expect these words to be mostly such as would have obvious connections with powerful emotions, particularly those associated with the reproductive instinct and such as are likely to be strongly repressed. Upon the whole this expectation is realized though with important qualifications. The 20 strongest words follow, together with the total number of indicators yielded by each:

to sin	156	to part	105
caring for	128	stern	99
friendly	118	abusing	98
supplicate	118	friend	98
fearing	117	dear	97
pride	115	marry	95
parting	112	nice	93
beating	111	yellow	92
angry	105	conduct	88
pity	105	prick	87

Perhaps half of the twenty words have a significance for erotic complexes, if interpreted in a broad sense. An even more striking tendency is the large proportion of words touching emotions of a distinctly painful coloring such as anger, fear and sorrow. This is particularly interesting in view of the recent tendency to assign a larger rôle to these latter emotions as a source of mental disorder. But of the strongly emotional

nature of these words there can be little doubt. Perhaps this may be most clearly shown by comparing them with the ten weakest words:

tree	33	mountain	28
needle	32	brother	26
village	32	hay	25
sleeping	31	finger	25
cow	31	month	15

The qualitative contrast between the two sets of words is marked to say the least.[1]

Upon the whole the men and the women show about the same number of signs on the various words. The four words *pray*, *lamp*, *needle* and *sad* (Table I.) have exactly the same number of indicators for each sex, while 80 of the remaining 96 words vary in their difference from one to ten points, with an average of four. *To sin*, which yields the largest number of indicators of all the words for both sexes alike, shows a difference of only four in the two scores. The men yield 80 indicators while the women yield 76.

A few words, however, differ greatly in the number of signs yielded by the men and the women. The words *fall*, *caring for*, *despise*, *pride* and *choosing* show this characteristic in such a marked degree that it can hardly be due to chance. The word *fall* for example, yields a difference of 22 points with the higher score being given by the women. This is easy to understand in the light of the common use of the word *fall* in a moral sense. The respective scores of 27 and 49 may perhaps be considered a quantitative expression of the double standard in sexual morality. *Caring for* also shows a difference of 22 points. In this case the men give the higher score. Next in size of the difference comes *despise* with 18 points, followed by *pride* with 17. In both these cases also the men

[1] It is noteworthy that one of the strongest of the stimulus words, *supplicate*, owes its high position not entirely to the emotional value in the sense implied above, but rather to the fact that its meaning was not known to 38 of the subjects! These were divided equally among males and females. This entirely irrelevant circumstance gave rise to many "indicators" such as failure to respond, long reaction-times, clang association and failure to reproduce original reaction at second presentation. The value of *supplicate* as a word for touching emotional complexes is therefore questionable. Fortunately this is the only word of the 100 the meaning of which was not known.

yield the higher score. *Choosing* comes next, showing a difference of 16 points with the women once more in the lead. The reasons for the differences of the last four words while tempting to speculation, are by no means so easy to find as in the case of the word *fall*.

In a number of other cases where the writers expected to find marked sex differences, none large enough to be significant were found.

III.

The Relative Frequency of the Various Alleged Complex Indicators

The utility of a given type of complex sign depends chiefly upon two facts: (1) The relative frequency of the appearance of this sign and (2) the diagnostic power or reliability of the sign when it does appear. Clearly the sign of an unfailing indicator is of little value if it is of rare occurrence and a sign no matter of how frequent occurrence, is of no value if it is nearly as likely to fail to indicate as to indicate truly.

The number of times each kind of indicator appeared with each of the 100 subjects was therefore tabulated by sexes, totaled and averaged. The final distribution of the 6,639 indicators yielded by the experiment is shown in Table II. The subjects average slightly over 66 complex signs each. Long reaction-time is the most numerous of all the signs, yielding 20.3 per subject. This is followed closely by repeated use of the same response word, and quite closely by defective reproduction of the response word. Next in importance but far less frequent comes repetition of the stimulus word with about one per subject. Failures to respond may probably be classed as unduly long reaction-times while the two remaining types are too infrequent of occurrence with the present group of subjects to yield reliable results from an analysis.

The sexes are remarkably equal in the total number of indicators, there being but one point difference between the totals of the two groups. But here the similarity largely ceases, as appears from an examination of the first two columns

of Table II. The women show 92 more cases of long reaction-time than the men, which is about 10 per cent. excess. In the case of failure to respond, which probably may be regarded

TABLE II.

Type of Indicator	Total Number of Appearances in:			Average Number of Appearances per Subject Irrespective of Sex
	50 Men	50 Women	Both Men and Women	
Long reaction-time	973	1,065	2,038	20.38
No response	20	30	50	.50
Repetition of stimulus word	187	266	453	4.53
Assimilation of stimulus word	42	60	102	1.02
Defective reproduction	1,094	820	1,914	19.14
Repeated use of the same response word	964	1,051	2,015	20.15
Strange or senseless reactions	34	26	60	.60
Obvious perseveration of idea	5	2	7	.07
Total	3,319	3,320	6,639	66.39

as an extreme form of long reaction-time, the women show about 50 per cent. excess. This agrees with the finding of Wells[1] that the women are prone to give long reaction-times, though the present writers are uncertain about attributing it to the fact that the experimenter was a man, as does Wells. If this were the case ought we not to expect the women for the same reason to show an excess in the other signs as well? As seen above this is not the case. Again the women show an excess of almost equal proportions in the repeated use of the same response word. Paradoxically enough these two types of indicators have a distinct *negative* correlation with each other (Table IV.). This means that repeated use of the same response word is associated with *short* reaction-times, rather than long.

But the greatest difference of all lies in the defective reproduction of the response word, where the men show 274 more signs than the women. This is an average difference of about five per person and amounts to over 25 per cent. excess. It is interesting to speculate as to why the men show this indicator so much more frequently than the women. A

[1] Wells, F. L., 'Some Properties of the Free Association Time,' *Psychol. Rev.*, 1911, Vol. XVIII., p. 7.

possible explanation may lie in the commonly observed fact that women, on the whole, tend to be more careful and conscientious in their reactions to all kinds of experiments, and especially show a greater interest in making a good personal score. It is not hard to see how the greater carelessness of the male subjects might lead to a greater number of false reproductions. At the same time the greater preoccupation of the female subjects with making what they feel to be appropiate responses may quite probably explain the excess of long reaction-times previously noted.

One of the largest proportional differences is in the case of repetition of the stimulus word. Here the women exceed the men by about 35 per cent. As pointed out by Jones,[1] this doubtless is a form of 'stalling' or defense reaction. The present writers incline to regard it as a peculiarly characteristic difference in the behavior of the two sexes. Because repeating the stimulus word consumes time, this fact would also account for nearly all the excess of long reactions among the female subjects. This excess of long reaction-time was 92, while the excess of repetition of the stimulus word was 79.

IV.

The Diagnostic Reliability of the Various Alleged Complex Signs

It has been previously pointed out that the value of a particular type of complex indicator depends not only on the frequency of its appearance but also upon its diagnostic reliability when it does appear. That the potency of the different indicators should vary from one another is almost self evident. Despite the apparent clinical value of such knowledge, neither Jung nor any other investigator so far as the present writers have been able to discover, has seriously raised the question as to the relative diagnostic efficiency of the various signs. From the general clinical accounts of the method[2] it would appear that all of the indicators are given about equal weight, with the exception that special impor-

[1] Jones, *op. cit.*, p. 407.

[2] Jones, *op. cit.*

tance is sometimes attached to lengthened reaction-time. In the present section we shall therefore attempt (1) to get some indication as to which of the various alleged complex signs are in truth associated with emotional complexes and (2) to secure some evidence as to the relative diagnostic power of those signs which appear to be valid.

The method of attack is almost of necessity an indirect one because of the presumably subconscious nature of some of the complexes and of the impossibility of obtaining honest introspections in many cases on other complexes which may be more or less clearly conscious. Stated in axiomatic form, the principle underlying the method is that, other things being equal, two variables related positively to the same variable are positively related to each other. For example, if all reaction-times of over thirteen fifths of a second were associated with emotional complexes, and all times shorter than this never were; and if in addition, defective reproductions always were associated with complexes, while successful reproductions never were; then of necessity, long reaction-times must always accompany defective reproductions and short reaction-times, successful reproductions. That is to say, there would be a perfect association between long reaction-times and defective reproduction because of their mutual relation to the complexes, and entirely apart from any natural affinity between the two indicators arising from their own proper natures. In such a case the degree or closeness of their association with each other would serve as a measure of their closeness of association with the complexes, *i.e.*, of their diagnostic reliability. If, however, upon computation we find that the degree of association between two alleged complex indicators is zero, we must conclude by similar reasoning and other things being equal, that one of them at least is not an indicator at all.

An excellent concrete illustration of this principle in a relatively clear form is found in the relation of long reaction-time to a number of other alleged indicators taken together. If long reaction-time on the one hand, and the several signs on the other, both indicate emotional complexes, then they

ought both to tend to fall together upon such individual stimulus words as touch complexes. Accordingly words which yield long reaction-times should on the whole show a considerably larger number of other complex signs than words with short reaction-times. This is, in fact, found to be the case when the number of the other indicators per 100 stimulus words is represented graphically for the various lengths of reaction-time (see heavy curve, Fig. 3). Both the principle under consideration and the excellent reputation of long reaction-time as a complex indicator[1] thus find support and confirmation in the marked and consistent rise of this curve with increasing length of reaction-time.

A limitation of the above method of measuring the diagnostic potency of the various types of complex signs remains to be pointed out. It lies in the possibility that tendencies to positive or negative association among the individual indicators may rise from other sources than the alleged mutual association between the individual indicators and the complexes. However, with a group of several indicators, the various possible *individual* affinities and repulsions which may exist among them apart from a common positive relation to the complexes, ought largely to neutralize each other. Thus the strength of the association found ultimately to exist between a given sign and *all other signs taken together* may be presumed to yield a useful indication of the closeness of association of the alleged sign with emotional complexes, and hence of its diagnostic reliability.

Jung himself recognized this principle[2] and made a limited use of it. He gives, for example, a proof based upon 2717 reactions from a variety of pathological and normal subjects, that defective reproduction of the reaction word is in truth a complex sign.[3] His proof however, though numerical, is qualitative rather than quantitative in its nature. While he shows that defective reproductions tend to be associated positively with long reaction-times, it seems not to have occurred to him to determine the strength or diagnostic power of this tendency. Yet he recognized that the reliability of

[1] Jones, *op. cit.*, p. 406.

[2] Jung, *op. cit.*, p. 188 ff.

[3] Jung, *op. cit.*, p. 191.

this indicator is distinctly limited. Fortunately one of his tables used in the above demonstration is so constructed that we were able to make the necessary computation for comparison with our own results.[1]

The method of computing the extent of association used in the present study may be illustrated by applying it to the relation of long reaction-times and the group of other complex signs just considered. The curve, as has been seen (Fig. 3), reveals a distinct tendency to association, but the *strength* of the tendency is not apparent. This may readily be determined by the following formula:[2]

$$r = \cos \frac{\sqrt{bc}}{\sqrt{ad} + \sqrt{bc}} \pi,$$

where r is a function comparable with Pearson's product-

TABLE III

FOUR-FOLD TABLE SHOWING RELATION OF THE LENGTH OF REACTION-TIME TO ALL THE OTHER INDICATORS LISTED ON PAGE 4 WITH THE EXCEPTION OF REPEATED USE OF THE SAME REACTION WORD

	Words Having One or More Other Indicators Exclusive of Long Reaction-times	Words Having no Other Indicators
Words having a reaction-time of more than 13-fifths of a second	(*a*) 840	(*b*) 1,200
Words having a reaction-time of 13-fifths of a second or less	(*c*) 1,510	(*d*) 6,450

[1] Jung expresses the principle as follows: "Sind nun diese Merkale wirklich bezeichnend d.h. hat die analytische Methode heir zu einem richigen und nachprüfbaren Resultat geführt, dann müssen die Merkmale im allgemeinen unter sich in nahen Beziehungen stehen, d.h. sich bei gewissen Assoziationen mit Prädilektion begegen also z.B. mangelhalfte Reproduktionen und zu lange Zeiten. Ist das nicht der Fall, und zerstruen sich die Komplexmerkale wahllos über den ganzen Versuch, dann hat allerdings die Analyse zu einem Fehlschluss geführt." The computation from Jung's table mentioned above, shows that there was an association of +.37 between long reaction-times and imperfect reproduction. This compares fairly well with the +.26 from our own results, when we consider that his subjects were largely pathological.

[2] Whipple, 'Mental and Physical Tests, Simpler Processes,' p. 48. While probably not so perfect, theoretically, as the more elaborate method of Pearson (Davenport, C. B., 'Statistical Methods,' p. 49 ff.) its use was more than justified by the enormous saving in labor of computation in a study already extremely laborious in this particular.

moments coefficient of correlation, π is 180° and the values of a, b, c and d are the respective entries in the four-fold table shown on page 125 (Table III.).

Substituting the values of the table in the formula, we have:

$$r = \cos \frac{\sqrt{1{,}510 \times 1{,}200}}{\sqrt{840 \times 6{,}450}\ \sqrt{1{,}510 \times 1{,}200}}\ \pi$$
$$= \cos .366 \times 180°$$
$$= +.408.$$

In round numbers then, + .41 is the strength of the tendency to association between long reaction-times and the presence of the other alleged complex signs, shown graphically in Fig. 3. While by no means perfect (1.00) it is definite and significant.

The probable error computed by the rough formula:

$$\text{P. E.}_r = \frac{1.1}{\sqrt{n}}$$
$$= \frac{1.1}{\sqrt{10{,}000}}$$
$$= .011$$

is probably not much in excess of .02. Since the n of all the other coefficients of association computed in this section is the same, .02 may be considered approximately the probable error of them all.

Proceeding as above, the coefficients of association were found between each of the five types of indicators which occurred frequently enough to give results (Table II.) and all of the other indicators massed together without distinction. These results are shown in column VI. of Table IV. It is seen that the repetition of the stimulus word is the strongest of all, giving a coefficient of + .53. Assimilation of stimulus word comes next with +.33. Long reaction-time comes third with + .24, defective reproduction is fourth with +.17, while repeated use of the same stimulus word comes last with the slight negative relation of − .06.

If taken at face value certain tentative conclusions may be drawn from these figures.

1. Repetition of the stimulus word is decidedly the most reliable diagnostic sign of the five indicators examined.

2. The first four are in all probability real complex signs.

3. Repeated use of the same reaction word is a complex sign of very doubtful diagnostic value, at least in the sense that the other signs are diagnostic. Ordinarily the appearance of the complex sign is supposed to apply to the stimulus word, meaning that the stimulus word has touched an emotional complex. The present evidence seems to indicate that repeated use of the same reaction word is somewhat more likely *not* to do this than it is to do so. There remains of course the possibility that the reaction may itself be sympto-

TABLE IV.

SHOWING THE COEFFICIENTS OF ASSOCIATION BETWEEN THE VARIOUS SIGNS AND GROUPS OF SIGNS.

	Repetition of the Stimulus Word	Assimilation of Stimulus Word	Long Reaction-time	Defective Reproduction of Reaction Word	Repeated Use of Same Reaction Word	All Other Indicators Massed Together	All Other Indicators Except Repeated Use of Same Reaction Word
	I	II	III	IV	V	VI	VII
Repetition of the stimulus word		+.41	+.69	+.14	+.24	+.53	+.586
Assimilation of the stimulus word	+.41		+.52	+.06	−.31	+.326	+.469
Long reaction-time	+.69	+.52		+.26	−.087	+.242	+.408
Defective reproduction of reaction word	+.14	+.06	+.26		+.017	+.174	+.259
Repeated use of the same reaction word	+.24	−.31	−.087	+.017		−.06	−.06

matic of a complex.[1] The present evidence has little or no bearing upon that question.

[1] Jones, *op. cit.*, p. 407.

It is a little surprising that long reaction-time should not show up any stronger in the series than it does. Indeed it would not have been beyond reasonable expectation to find it ranking first, in view of its great reputation as a complex indicator. It actually ranks third with a coefficient of + .24, which is less than half as strong as that of the repetition of the stimulus word. The present evidence, while not final owing to the limitations of the method pointed out above (p. 124), at least raises some presumption against the pre-eminence among complex signs now enjoyed by long reaction-time.

In order to analyze in further detail the origin and inner constitution of the above tendencies to association, the coefficients of association were computed between each of the above five indicators among themselves, by pairs, in all the possible combinations. These appear in the first five columns of Table IV. Here we may expect the individual affinities and repulsions among the various indicators to appear with some clearness. The strongest of these affinities (with a coefficient of + .69) between long reaction-time and repetition of the stimulus word, is obviously due in part to the fact that the repetition of the stimulus word itself takes time, and directly contributes to increasing the length of the reaction. The next highest is between assimilation of the stimulus word and long reaction-time, with a + .52. Perhaps this may be attributed to a certain amount of real misunderstanding of the stimulus word with the consequent accompaniment of a period of doubt before the decision (and so the reaction) could be made. A similar mechanism tends to account for the correlation of + .41 between assimilation and repetition of the stimulus word, since in the real uncertainty of understanding a word, we naturally tend to repeat it in a questioning tone to verify our interpretation.

In all of the cases of negative or practically zero correlation, we find involved the repeated use of the same reaction word. This tends to confirm our doubts expressed above (p. 127) of the diagnostic reliability of this alleged sign. The − .087 shows that repeated use of the same reaction word is, upon

the whole, positively associated with *short* times rather than with long, though it might conceivably be associated with both (as contrasted with medium time) provided the line of regression were curved in a certain manner. This possibly will be examined in detail below. The only positive coefficient of any size involving repeated use of the same reaction word is with repetition of the stimulus word, + .24. This is extremely interesting, but not easily explained by the available facts.

In view of the very doubtful showing made by repeated use of the same reaction word, it was thought that avoidable distortions might have entered into the results in column VI. from its inclusion in the massed indicators. Therefore correlations were computed anew between each of the four apparently significant signs and all of the other indicators massed together except repeated use of the same reaction word. These results are given in column VII. It is seen at once that in all cases there is a marked increase in the degree of association, though the relative strength of the various indicators remains the same.

V.

Diagnostic Potency as a Function of the Length of Reaction-time

Instead of being of the presence-absence type of variable as are most of the other alleged complex indicators examined above, reaction-time is a continuous variable and for that reason offers certain advantages in the way of further analysis. Thus far we have tacitly assumed that all reaction-times longer than thirteen-fifths of a second indicate emotional complexes, while all shorter times do not. We now know (p. 127) that this is not always true, though a correlation of + .24 indicates that it is more apt to be true than false. The question still remains: At what point on increasing reaction-times do they first begin, upon the whole, to indicate emotional complexes? Is there a sharp cleavage at this point between the critical and the non-critical times, or is the transition gradual and continuous?

And what about short reaction-times? It has been stated by several writers that very short reaction-times also indicate emotional complexes.[1] Watson, in discussing this matter, says,[2] "The indicators of implicit response or tension obtained from the subject are unduly long reactions . . .; significant response words . . .; *too rapid responses* . . .; low level responses; failure in response . . ." (italics ours). To be sure the decided positive correlation found above between long reaction-time and the other indicators massed together, means superficially that there is *negative* correlation between those indicators and short times. The question can not however, be answered in this summary manner, for correlation coefficients are based upon the assumptiom of a straight line of regression. In the present case, on the contrary, it is conceivable that the line of regression might be in the shape of a very broad and low U with one upright arm somewhat higher than the other.[3] In such a case both extremes of time would be complex indicators, as contrasted with the intermediate times, though the long times would be stronger indicators than the short.

The obvious way to settle such questions as those raised above is to plot the actual curve of the relation in detail. This consequently was done. The indicators of the 10,000 reactions were tabulated according to the absolute time of each. We then found the average number of complex signs per hundred words falling on each length of absolute time from the longest to the shortest. These averages were based on groups varying from 500 to 1,000 reactions. They were then plotted and appear as the continuous line, Fig. 2. In order to locate the point at which increasing reaction-times become critical, a horizontal line was drawn at such a level that it would represent the number of indicators per hundred words if the indicators were distributed indifferently throughout all lengths of time. Wherever the curve rises above this line, then, at that point it begins to exceed a chance frequency,

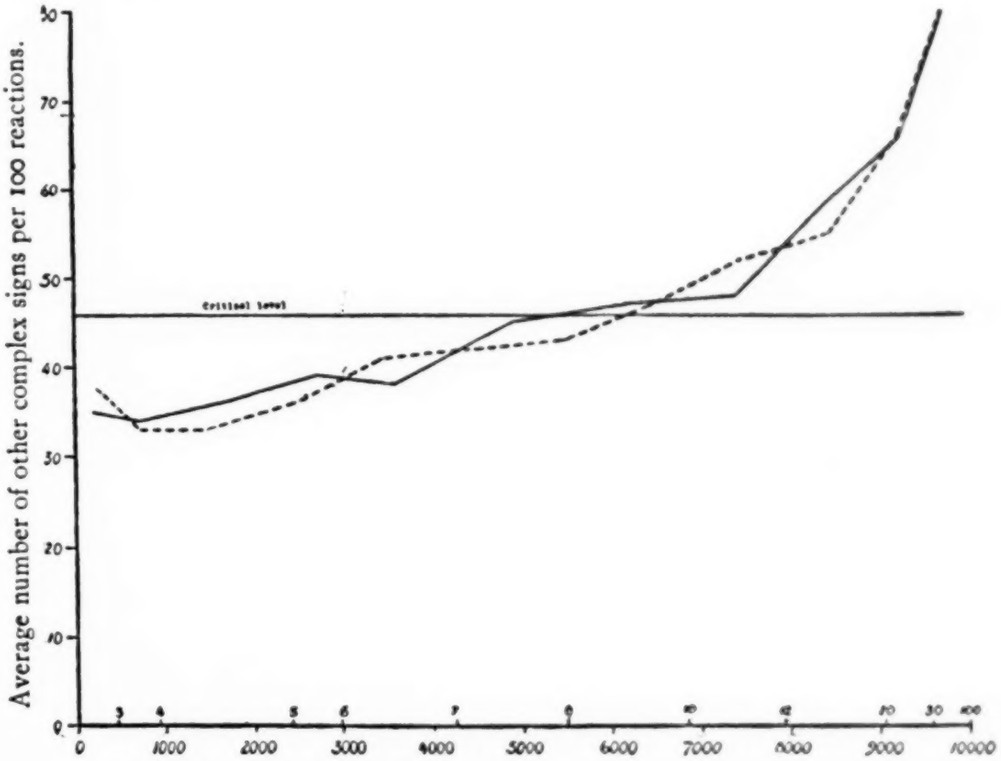
[1] Dooley, 'Lucile,' *op. cit.*, p. 132.

[2] Watson, J. B., 'Psychology from the Standpoint of a Behaviorist,' p. 208.

[3] Yule, G. U., 'An Introduction to the Theory of Statistics,' p. 162f.

i.e., it becomes significant; and the higher it rises the more significant it becomes.

An inspection of this curve shows that the critical point on increasing reaction-time, falls not far from nine fifths of a second. The excess above chance does not become sufficient to be practically significant, however, until about thirteen or fourteen fifths of a second, which agrees very well with current



Order of reactions from shortest to longest.

———— According to the absolute method.

— — — — According to the relative method.

FIG. 2. Curves showing the relation of all the other complex signs massed together, to length of reaction-time. The figures *above* the base line represent length of reaction-time in fifth-seconds.

practice.[1] This curve also shows very clearly that there is no sharp division between the critical and non-critical reaction-times but that they pass over from one to the other by a most gradual and continuous movement. The only suggestion of such a cleavage lies in the fairly marked upward bend in the curve at about twelve fifths of a second which

[1] Brill, *op. cit.*, p. 140.

continues at a positive acceleration until the end. When plotted with a base line strictly according to absolute units of the time however, and not according to the temporal ranking of the reactions themselves as in Fig. 2, the curve becomes one of negative acceleration, *i.e.*, tending to the horizontal.

Lastly, the curve gives scant support for the claims made on behalf of short reaction-time. It is true that there is a suggestion of a secondary rise at the lower tip of the curve, and while probably a real tendency as we shall see later, it does not approach even remotely the level of diagnostic significance.

Since the above curve was based on the absolute reaction-time and since subjects differ greatly in the general rate of their reactions, many fast subjects' records are not represented at all on the right of the above curve while many slow subjects' records are not represented on the left end of the curve. The question naturally arises as to whether a method based on absolute times is as diagnostically significant as one based upon *relative* times. Clearly if an analogus curve were plotted according to the relative method and the downward slope from right to left should be found more steep in the latter case, the relative method would be shown the more significant. Accordingly each of the 100 reactions of each of the 100 subjects were tabulated anew, this time relatively. The number of indicators per 100 reactions was found for the five longest reactions of each subject (500 reactions in all), for the next five longest reactions, for the next ten longest (1,000 in all), the next ten and so on until at the short reaction-end, we descended the last two steps by 5's again. The two short steps of 5's at each end of the series, were made with the purpose of securing a little more detail at those especially interesting points. The curve appears as the broken line, Fig. 2.

When we consider the marked difference in the actual data represented in the corresponding parts of the two curves and especially at the ends, they appear astonishingly similar. This detailed similarity can only mean that on the long run at

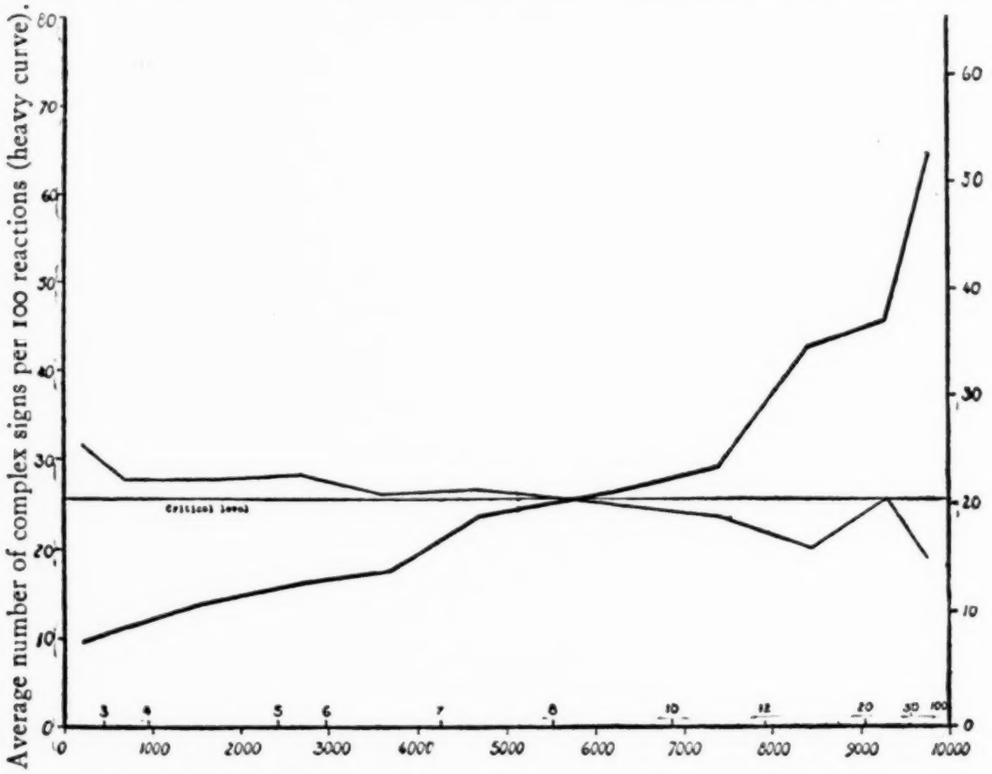
least, one method is diagnostically as potent as the other. It is evident, then, that in so far as two methods differ, any potency peculiar to one method must be duplicated by an equal potency peculiar to the other,[1] and that the two individual potencies must follow the same law. No doubt this law is essentially the same as that of the central potency shared by both methods, *i.e.*, waxing in its progress from left to right in Fig. 2. Accordingly a combination method which would give joint weight to each ought to yield a higher diagnostic value than either method alone. This depends in the last analysis upon the fact shown by the above curves, that where one method includes more reactions from a given subject than the other, there exists on the long run, a significant potency in the longest of these reactions. For example, the above curve shows that the limit of practical diagnostic significance is about the fifteenth from the longest reaction. By the absolute method it is not far from thirteen fifths of a second. If in a given subject there were 35 reactions longer than thirteen fifths of a second and by the relative method only 15 reactions could be included, the joint method would make an equal concession to each method and take the longest 25. In another case there might be but one reaction longer than thirteen fifths of a second yet the relative method would demand 15. The joint method would then use the longest 8 reactions. It would be a relatively simple though somewhat laborious task to test empirically the truth of this theory.[2]

It will be noted that at the lower end of the broken curve we find the same upward rise previously noted in the other, only in this case it is much more marked. In order to get further light on this matter, the data was plotted for the men and the women separately and the rise was found in both alike. Without doubt it is a real tendency. Later we shall find an explanation for it.

[1] Partial correlations (Yule, *op. cit.*, pp. 239 ff) show that only about one third of the potency of each is shared by the other.

[2] This may be done rather easily, however, by Yule's method of multiple correlation (Yule, *op. cit.*, p. 248). This indicates that by combining the two methods as indicated above, the potency will be increased about 20 per cent. over either method independently.

The negative association of .087 obtained above between repeated use of the same response word and long reaction-times, raises the question as to the exact relation of these two alleged signs. As has been suggested in another case, it might well be that here also a curved line of regression would be found such that repeated use of the same reaction word would correlate both with short and to a lesser extent but positively also, with long reaction-time. To determine this the



Orders of reactions arranged from shortest to longest.

——— Repeated use of the same response word, absolute method.

▬▬▬ All of the other alleged complex signs except repeated use of the same response word, absolute method.

FIG. 3. Showing the relation of various complex signs to length of reaction-time. The figures *above* the base line represent length of reaction-time in fifth-seconds.

entire 10,000 reactions were again tabulated according to time to determine the exact relation of repeated use of the same reaction word to long and short reaction-time. The curve was plotted according to the same plan as that in Fig. 2. It is the lighter curve, Fig. 3. It shows at once a distinct and consistent correlation with short times. For the most part, it is surprisingly smooth and straight.

By subtracting the various parts of the data for this curve from the corresponding parts of the data for the original curve of Fig. 2, we obtain data for the plotting of the curve of the relation of the four other indicators, to reaction-time. It will be recalled that this relation yielded an association coefficient of + .408. The curve appears as the heavy line in Fig. 3. Here we find the curve distinctly steeper than the corresponding curve of Fig. 2. The rise at the lower end of the curve in Fig. 2 has also entirely disappeared. There is evidently no tendency whatever for these indicators to be connected with short reaction-time. The rise at the lower end of the original curve was evidently due entirely to the influence of repeated use.

Do the above results mean that short reaction-times and the repeated use of the same response word are both to be excluded from the list of complex indicators? So far as the present method can decide the matter with normal subjects, the writers are inclined to answer in the affirmative. It is true, these two alleged indicators are mutually related to the extent of + .087. While this coefficient is doubtless real in the sense that it is several times that of the probable error, it still is very small and probably no more than a natural individual affinity between the two types of reaction. There remains of course the possibility that the two alleged signs may be a weakly allied diagnostic group, significant with respect to the reaction word itself and not to the stimulus word, as is assumed to be the case with the other signs. The answer to this question must await further investigation.

VI.

The Diagnostic Potency of One Indicator vs. Two

In psychanalytic literature the notion is sometimes expressed or implied that when a stimulus word evokes a single complex sign, no particular significance is to be attached to it; but if two or more signs appear, the combination at once becomes decidedly significant.[1] This necessarily means that

[1] Dooley, *op. cit.*, p. 148.

the second indicator makes a very much greater increment to the diagnostic potency than the first. The question therefore arises as to how much if any increase in the diagnostic significance is added to one indicator by the presence of a second?

The indirect method utilized so largely above furnishes us with a ready means of getting at least an approximate answer to this question. To illustrate, a tabulation of certain data for this purpose showed that long reaction-time and defective reproduction falling together on the same stimulus word, attract the repetition of the stimulus word, 18.1 per cent. of the cases. On the other hand long reaction-time separately, attracted it 16.6 per cent. of the times, while defective reproduction attracted it 7.3 per cent. of the times, the two independently making an average of 12.7 per cent. Thus the two together show a gain of 5.4 points or 42½ per cent. over the two separately. From the data of the four strongest indicators investigated above, it is possible to find twelve different combinations such as just described. These differ much, as might be expected, but a weighted average of them all, probably does not depart very far from the truth. The computation shows that two given indicators are 64.8 per cent. more likely to attract a given third indicator than either one of them is likely to attract it separately. This suggests that while two indicators are distinctly more significant than one, the second indicator adds by no means as much diagnostic potency as the first, to say nothing of more.

The increment in diagnostic potency contributed by the addition of a third or fourth indicator, while of great interest and some practical importance, was not investigated. Presumably the increase in diagnostic potency resulting from the addition of successive indicators would follow a law of diminishing returns.

EFFECTS SIMULATING FATIGUE IN SIMPLE REACTIONS

From the Psychological Laboratory of McLean Hospital[1]

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1. The time of the simple reaction process has generally been regarded as very resistant to fatigue. Observations by Cattell have given the chief ground for this view, but his classical experiments (1) on this subject hardly show such absence of fatigue loss as to justify regarding the question as closed. There were studied discriminative reactions to light, letters and other associations, as well as simple reactions to light and sound. Observations covering periods of about 16 hours were made with two subjects. Signs of fatigue are variable, but certainly present in various series. The final light reaction series for Subject *C* is 122 per cent. of the initial reactions series; in Subject *B* this fatigue effect is hardly traceable. Both subjects show moderately increased times for letters, and for the associations the final time averages in *B* 131 per cent. of the initial, for *C* 113 per cent. Simple reaction time to sound cannot be said to show a loss in either subject. It is observable that variability of reaction times does not change in proportion to the length of the reaction times themselves; also that there is generally more loss on the visual side, where the chances of sensory fatigue are greater; also that there is more fatigue loss in the more automatic functions, where it is less offset by practise.

2. In the series reported by Bettmann (2), of 1,000 (apparently to sound) choice reactions made in two hours, the score for the final fifth is 108 per cent. of the initial fifth. Woodrow (3) reports shorter reaction times obtained at the end of an hour's reaction time work of similar character to the present,

[1] As of August 1, 1920.

but under conditions more generally stimulating to the subject.

The present experimental facts are soon told. When 216 reactions are taken under the conditions of these experiments (4), the reaction time in the second 108 reactions averages close to 105 per cent. of that in the first 108, as appears in the following figures:

PER CENT. WHICH THE REACTION TIME SCORE IN THE SECOND HALF OF THE EXPERIMENT IS OF THE SCORE IN THE FIRST HALF

Subjects	A-group (13 Persons)	*K*	*W*
Av.	104.9	105.1	106.3
M.v.	4.9	4.8	3.5

3. Variability within each unit reaction-series (27 reactions) is indicated by the per cent. which its *upper* quartile is of its median. This figure is termed the 'quartile ratio.' It is observed that while the central tendencies are longer in the second half (par. 2), this lengthening is unaccompanied by corresponding increase in the quartile ratios. These are quite stable, as follows:

PER CENT. WHICH THE QUARTILE RATIOS OF THE FIRST HALF ARE OF THE QUARTILE RATIOS OF THE ENTIRE EXPERIMENT

Subjects	A-group	*K*	*W*
Av.	49.9	50.2	49.8
M.v.	1.2	.7	.4

4. It runs counter to the weight of evidence to suppose the loss due to actual effort in the repeated reactions themselves. The series last some forty minutes each, and there is a recovery period between single observations of about eleven seconds. Appeal can hardly be taken to exhausting character of the work itself.

5. More suitable interpretation is found in certain special conditions of the work. The room in which it takes place is considerably darkened, to permit reading of a galvanometer scale. The subject's only sense stimuli incidental to the experiment are the closing of the experimenter's key for the get-ready signal, the get-ready signal itself, the stimulus for reaction, and whatever noise or other disturbance the subject

makes in his own responses. The galvanometer chronoscope operates entirely without noise. The average interval between stimuli is slightly over 11 seconds, which makes the reactions seem very discontinuous. As an experiment progresses, the subject is apt to show signs of increasing somnolence, yawning or stretching, etc. The writer (*W*), found it the most *ennuyant* of experiments, as the doctor of physick his own draught, until it became possible to perform it 'from the spinal cord.' Part of this 'logeyness' induced by the conditions, seems to be a slightly increased refractoriness to the simple reaction process. It is well to note that while the reactions become definitely longer, they do not become more variable (par. 3). The loss does not involve a diminution of attentional control, as expressed in tendency of attention to occasional lapse. It is rather an upward thrust of the whole distribution.

6. There appears in these experiments a decrease in functional efficiency under continued exercise of the function. The question if fatigue is a term properly applicable to such decrease leads into a somewhat casuistical discussion. Thorndike (5) has regarded it as a characteristic of fatigue, that it shall be a condition improvable by rest. It is improbable that the phenomena meet this criterion, as rest is ordinarily conceived. A lessening or temporary cessation of the experimental work, or a further lessening of the already slight general stimulation which the environment of the subject affords, would be likely to further decrease his efficiency, or abolish it entirely by putting him to sleep. The 'rest' that would cure this decreased efficiency would be some relief from the rather depressing experimental conditions described.

7. The writers favor regarding this slowing of reaction time as a fatigue effect, under the concept of fatigue as a name including all influences by which the continuance of a task tends to decrease its efficiency. Accumulation of fatigue toxins as result of either mental or physical overexertion seems to be here ruled out. Secondary effects of disagreeable sensations from such exertions seem also ruled out. The effective

factor is rather a 'monotony,' and its result, a raising of the reaction threshold.

8. It may be asked if there is any difference of sound and light stimuli in this respect, as these sensations differ so much in their own fatigue phenomena. A generally negative answer is implicit in the findings of a previous paper. In both halves of the experiment, the sound-light ratios (per cent. which the light time is of the sound time) are similar for the A-group of thirteen subjects and for Subject *W*. In Subject *K* the sound-light ratios are clearly less in the second half; that is, the sound reaction has lost *more* than the light. This is the opposite of what would be expected from a sensory fatigue effect.

9. A similar question may be asked regarding the two different prestimulus (get-ready) intervals employed; whether the monotony and consequent 'logeyness' have the more effect on a one-second or a three-second prestimulus interval. As expressed in the A-group, the general effect is that the monotony is especially unfavorable to the longer, three-second, prestimulus interval. The average difference in favor of the one-second interval in the second half, is the same for sound and light. The differential effect on the prestimulus intervals does not appear in *K* and *W*, there being substantial equality throughout their records. This should be taken in connection with the presumably lesser conscious attention in these subjects during their repeated series. In *W* especially, the process was little short of automatic, with no conscious attention to the interval employed.

For the A-group, the longer times in the second half are essentially due to the results with the three-second interval. The difference for the one-second interval is hardly significant. The figures are as follows, in which there again appears the tendency to smaller variations in the results for light:

PER CENT. WHICH THE SCORES FOR THE TWO PRESTIMULUS INTERVALS IN THE SECOND HALF ARE OF THEIR SCORES IN THE FIRST HALF; (A-GROUP ONLY)

	Sound, 1″	Sound, 3″	Light, 1″	Light, 3″
Av.	102.7	108.1	101.2	107.0
M.v.	7.3	11.5	5.9	3.9

10. In respect to the general disfavoring in the A-group of the longer interval by the monotony, the indication is that the 'fatigue' of monotony makes it little if at all harder to *rouse* the attention (to a one-second interval), but rather harder to *hold* it (to a three-second interval). This is the early monotony effect. With the subjects accustomed to experimental conditions, *K* and *W*, the monotony effect is more evenly distributed to both prestimulus intervals.

11. It is a fate of concepts either to die barren, or to perish in bringing forth new ideas. 'Secondary dementia,' the Freudian sexuality, the Binet intelligence, herein bear the better part. A similar destiny perhaps awaits the concept of fatigue. The fundamental implications of the term are two: continued subjection to certain working conditions, and decreased effectiveness of *some* response. There are various formulations of how the first of these brings about the second. They are given in terms of toxins, reflex inhibitions, refractory phase. Monotony has also been cited as a factor in fatigue effects. The word implies a feeling of disagreeableness resulting from sameness. It is reasonable to regard this disagreeableness as secondary to an increasing *difficulty resulting from sameness*, as well as from general lack of environmental stimulation, and to include it in a broad conception of 'refractory phase.' It may be noted that saying the reaction time is increased in the second half of the experiment is the same as saying that it requires a greater stimulus in the second half to keep the reaction time at its former level; the reaction threshold is by so much raised.

12. In sum, the present experimental conditions are such as to make the reaction times in the second half of a forty-minute experiment, average some 105 per cent. of those in the first half. These conditions, with their moderate work and ample rests pretty well exclude exhaustion in the lower nervous arcs and allow a monotony effect to appear in relatively pure form. A distinctive feature of it is selective action on the longer, three-second prestimulus interval. Again, it does not alter the variability of the reaction times, which showed some tendency to grow greater in the results

of Cattell. The alertness aroused by the get-ready signal is not so well maintained under monotony as at the beginning, but it does not fluctuate any more under monotony.

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'SUBJECTIVE' PERCEPTIONS

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TABLE OF CONTENTS

I. Introduction and Object 143
II. Results 144
A. Cognitive Classification 144
B. Attributive Classification 150
C. Conditions of Occurrence 154
(1) Complexity of Material 154
(2) Position of the Subjective Reports 155
(*a*) Fixation 156
(*b*) Clearness 157
(*c*) Order of Report, 'Set.' 157
(3) Duration of Exposure 159
(4) Quality 159
(5) Practice 160
(6) Fatigue 161
III. Summary of Results 162

In an experiment published some time ago by C. A. Britz,[1] in which he asked his observers to describe a field of colored rectangles presented tachistoscopically, figures were occasionally reported which were not present in the physical stimulus. These figures were regarded by Britz as 'subjective,' and as such received no further consideration in his published paper.[2] Subsequently we repeated Britz's experiment[3] and our observers also gave 'subjective reports.'[4] In the exposition and report of this work we too excluded them from our classification[5] and considered and listed them separately.[6]

[1] C. A. Britz, 'Eine theoretische und experimentelle Untersuchung über den psychologischen Begriff der Klarheit,' Saarlouis, 1913.

[2] *Op. cit.*, 56.

[3] Karl M. Dallenbach, 'Attributive *vs.* Cognitive Clearness,' JOUR. OF EXP. PSYCHOL., III, 183–230.

[4] The terms 'objective' and 'subjective' are used without prejudice. 'Objective' is used to designate the cases in which there is a physical correlate on the stimulus card; and 'subjective' is used to designate the cases in which there is no known physical correlate.

[5] *Op. cit.*, 189.

[6] *Op. cit.*, 188–189, and Table II., 195.

Not, however, from a conviction that this procedure was justified, but wholly because in this part of the work, that is, in the analysis of the perceptual phases, we desired to reduplicate Britz's conditions and to follow as closely as possible his schema of classification. Not to have done so would have exposed us to the criticism that we had changed the criteria of classification; and, since we were able to extend his classification from 10 to 17 steps, might also have prompted the suspicion that the extension was due in all probability to this change.

Britz's justification for the elimination of the 'subjective reports' may, however, be seriously questioned. For, in the first place, the present-day psychology of perception admits that the distinction between sensory and imaginal elements is purely logical and not psychological; and, in the second place, the comparison of a perception with an exposure field can be made only upon the assumption that the stimulus is physical and not physiological. Furthermore, where, as in this case, we are concerned with a problem of clearness, any question which might be asked concerning the sensory might also be raised concerning the imaginal elements. It would seem, therefore, that there is no *a priori* reason for the elimination of the 'subjective reports,' and if there is any *a posteriori* ground for such a procedure it can be found only in a study of the results themselves.

In the hope of answering these questions we have reexamined our original data, culled out all subjective reports, and subjected them to the same sort of analysis that the objective reports received in our earlier paper, and we have also compared at every stage the two sets of results.

Results

A. Cognitive Classification

In the cognitive classification of the subjective reports 10 of the 17 steps obtained in the earlier work were again obtained: 6 were found in *W*'s (Professor H. P. Weld's) reports; 7 in *F*'s (Professor W. S. Foster's); and 5 in *D*'s (the author's) reports.

The lowest step that we marked in the earlier work was one in which the observers described their impressions as 'spots,' 'flecks,' 'blurs,' without being able to say anything definite about form, size, quality or number. Only one of the observers, *W*, gave a subjective report of this nature. After an exposure of a card of Series II. (six rectangles) he accounted for six 'spots' and then continued, "All others—I guess there were one or more, I cannot say,—were vague."

The second step, in which a specific number of indefinite forms was reported, was identified in the subjective reports of all of the observers. Examples are:

W (7). (After an exposure of a Card of Series II., 6 rectangles.) "I saw seven areas."

F (50). (Card of Series II.) "My impression is of 7 areas."

D (78). (Card of Series II.) "Perception of 7 areas. Haven't the least idea of the quality of second. [The second was the subjective, for the descriptions of 1, 3, and the others were identical with the physical stimuli.] I cannot say whether the area was colored, or even whether it was rectangular."

The third step, in which a tint was ascribed to the indefinite impressions, did not appear in the subjective reports; but the fourth step, in which the impressions were described as colored, was found in the reports of two observers:

W (11). (Card of Series II.) "Blue, left to right . . .; red, to left of center . . .; five or six other colors were there."

D (19). (Card of Series II.) "Perception of 7 colored areas, B, P, O, —, —, —, —. [Blue, purple, and orange were the qualities of the three rectangles to the left of the card.] The areas to the right were unclear. Can report only that they were colored. I have no idea of the hue, tint, or chroma; did not perceive shape; know only that they were colored."

The fifth, sixth, seventh and eighth steps were not identified in the subjective reports of any of the observers.

The ninth step, in which a definite number of rectangular areas was cognized, was identified in the subjective reports of all observers. Examples are:

W (123). (Card of Series II., 6 rectangles.) "Blue . . ., yellow . . ., red . . . and four others."

(142). (Card of Series I., 5 rectangles.) "Green . . ., orange . . ., purple . . ., yellow . . ., and two others."

(163). (Card of Series II.) "Blue . . ., red . . ., yellow . . ., and three others."

F (15). (Card of Series I., 5 rectangles.) "Six rectangles, —, violet, —, gray, —, blue."

(40). (Card of Series II.) "My impression is of 8 rectangles, O, G, R, —, Bk, —, B, —; . . ."

(41). (Card of Series I.) "Yellow, red, green, —, —, blue. I think there were six colored rectangles."

D (116). (Card of Series II.) "Seven rectangular areas, named in order from left to right: Bk, B, R, Y, —, —, —. . . . Cannot report further about the quality of the three to the right; was only dimly aware of them."

(182). (Card of Series I.) "Six rectangles: B, G, B, Bk, —, —; . . . I am unable to add to my report of the last two."

(237). (Card of Series II.) "Seven rectangles: R, O, B, Y, —, —, —."

Isolated cases of the tenth step, in which a tint was ascribed to the rectangular forms, were obtained from all the observers:

W (97). (Card of Series II.) "Y . . ., P . . ., R . . ., and I should say four others. These appeared as grays, some darker than others."

F (10). (Card of Series I.) "Six rectangles: —, O, P, —, B, —. The last [the areas for O, P and B corresponded to the 2, 3 and 5 objective stimuli] was dark to medium tint."

D (64). (Card of Series II.) "Seven rectangles: R, Y, Gy, —, —, —, —. Have general impression that the unnamed areas were dark."

The bulk of the subjective reports was found at the eleventh step, in which the rectangular forms were described as colored: 62 per cent. of *W*'s and 78 per cent. of *F*'s reports were grouped here.

W (18). (Card of Series I.) "Six rectangles, blue last to right, good chroma, dark tint; red last to left, was also of good chroma and dark tint. There were four other colors which I cannot name."

(117). (Card of Series II.) "Seven rectangles: Bk . . ., B . . ., R . . ., and four other colors."

F (26). (Card of Series I.) "Impression of six colored rectangles. . . ."

(205). (Card of Series II.) "About 8 colored rectangles: Y, B, Bk, grey, purple, colored, colored, colored. . . ."

D (70). (Card of Series II.) "Eight rectangular areas, all colored. Cognized the colors from right to left: B, Bk, R, salmon. Haven't the least idea of the qualities of the other areas, although I know that they were colored."

(102). (Card of Series I.) "Perception of 6 colored rectangular areas. . . ."

The eleventh step was the highest of the cognitive phases that we were able to identify in the subjective reports of *W* and *D*. *F*, however, gave reports which could be classified at still higher levels. None was obtained from his reports at the twelfth, fifteenth and sixteenth steps, but several were obtained at the thirteenth step, and isolated cases were obtained at both the fourteenth and the seventeenth steps.

Examples of the cases at the thirteenth step, in which a specific quality was named, are:

F (32). (Card of Series I.) "Six rectangles: G, Bk, Y, P, B, Gy. I reported the colors to myself in order of reading and as recorded above; simply saw the colors clearly and at once said them, not, I think, on basis of memory after-image. Indeed when I came to ask myself the nature of any of the colors after reporting them I couldn't get a single color to pop up sensorial-fashion as they do in the memory after-image, or in 'immediate memory.'"

(117). (Card of Series II.) Named in his habitual way from center to left and then from center-right; "Grey, P, B, Bk, Y, —, grey. . . . The greys were of the same quality."

TABLE I

SHOWING THE VARIOUS COGNITIVE PHASES IDENTIFIED IN THE SUBJECTIVE REPORTS, THE NUMBER OF CASES OCCURRING AT EVERY PHASE, AND A DIVISION OF THESE CASES ACCORDING TO THEIR ATTRIBUTIVE CLEARNESS

Degrees of Cognition		Observer														
		W					*F*					*D*				
		Clearness					Clearness					Clearness				
		Not Reported	One Level	Two Levels		Total	Not Reported	One Level	Two Levels		Total	Not Reported	One Level	Two Levels		Total
			Upper	Upper	Lower			Upper	Upper	Lower			Upper	Upper	Lower	
Indefinite form																
Others experienced	1				1	1										
A definite number experienced	2				1	1				3	3	2			4	6
Tint	3															
Colored	4				14[1]	14									2	2
General quality	5															
Specific quality	6															
Hue, tint, chroma	7															
Definite form																
Others experienced	8															
A definite number experienced	9	14	4		7	25				8	8	4	2		8	14
Tint	10		1			1				1	1		1		1	2
Colored	11	20	23		26	69	17	55		1	73		2		2	4
General quality	12															
Specific quality	13							6			6					
Hue and tint	14							1			1					
Hue and chroma	15															
Hue, tint and chroma	16															
Paper character	17							1			1					
Total		34	28		49	111	17	63		13	93	6	5	17		28

[1] One case included here was reported as at the third level; see earlier work, pp. 195, 225–227.

The report which we classified at the fourteenth level, in which a description of hue and tint was given, is:

F (98). (Card of Series II.) "Seven: B, Bk, BG, P, V, Y, dark grey." The objective stimuli were Bk, B, G, R, P, V. It is therefore obvious that the Y which *F* described further in his introspection as "light" was the subjective quality in this list.

The report placed at the seventeenth level, in which the paper character was described, is:

F (205). (Card of Series II.) "About 8 colors: Y, B, Bk, grey, P, —, —, —. . . . The Bk was not the velvet black, but the smooth one." The objective qualities were Y, B, grey, P, V, O; so it is again obvious that the Bk, which *F* described fully and which he inserted between B and grey, is subjective.

A résumé of the various cognitive phases which we were able to identify in the subjective reports is given in Table I., which shows in the 7, 12 and 17 columns, under the caption 'Total,' the total number of such reports given at the different cognitive levels by every observer.

A comparison of Table I. with the analogous table of the earlier work (Table II., p. 195) reveals, in spite of the fewness of the subjective cases involved, striking resemblances in the cognitive distribution of the two kinds of reports. These resemblances are more clearly shown in Tables II. and III. which follow.

TABLE II

SHOWING THE TOTAL NUMBER OF TIMES THE SUBJECTIVE REPORTS WERE WITH AND WITHOUT A DEFINITE FORM, AND A DIVISION ACCORDING TO THEIR ATTRIBUTIVE CLEARNESS

Observer	Report of Form	Attributive Clearness				Total
		No Report	One Level (Upper)	Two Levels		
				Upper	Lower	
W.....	Indefinite.....	0	0	0	16[1]	16
	Definite.....	34	28	0	33	95
F.....	Indefinite.....	0	0	0	3	3
	Definite.....	17	63	0	10	90
D.....	Indefinite.....	2	0	0	6	8
	Definite.....	4	5	0	11	20

[1] One case included here was reported as at the third level; see earlier work, pp. 195, 225–227.

Table II. is analogous to Table III. (p. 196) of the earlier work. Both of these tables show that in comparatively few reports were the perceptions without definite form. The percentages of the cases which were with and which were without definite form for two of the observers, as is clearly shown in Table III., are nearly identical for the objective and the subjective reports.

TABLE III

SHOWING A COMPARISON OF THE 'FORM' OF THE PERCEPTION IN THE OBJECTIVE AND SUBJECTIVE REPORTS

Observer	Report of Form	Percentages	
		Objective Reports	Subjective Reports
W	Indefinite	14.6	14.4
	Definite	85.4	85.6
F	Indefinite	1.7	3.2
	Definite	98.3	96.8
D	Indefinite	5.3	28.6
	Definite	94.7	71.4

The reports of *W* and *F* show practically no difference in the 'form' division: 85.4 per cent. and 98.3 per cent. of the objective reports, and 85.6 per cent. and 96.8 per cent. of the subjective reports are of definite form for *W* and *F* respectively. *D's* results are not in such close agreement: 94.7 per cent. of the objective reports are 'definite' in form, whereas only 71.4 per cent. of the subjective reports are so distinguished. This discrepancy, however, is not large. The preponderance of cases in both kinds of reports is in the same direction—that is, in the direction of definiteness—and though the percentages are not identical, as they may be said to be in the cases of the two other observers, they are close enough, particularly when the small number of subjective cases reported by *D* is considered (which is probably due, not to the fact that he was a more objective type of observer, but to the fact that he had constructed the exposure-cards and was familiar with their schema and construction), to justify us in concluding that, from the point of view of definiteness and indefiniteness of form, the subjective and objective reports do not differ.

There is some indication, however, that the highest degrees of cognition are, except in rare and unusual cases, limited to the reports which have a definite and known objective correlate. *W* and *D* give no cases above the eleventh step, and *F* but two above the thirteenth. The apex of the curves of the objective reports (cf. Table I., p. 195, of the earlier work) lies for observers *W* and *D* at the sixteenth step, whereas the apex of the subjective reports (cf. Table I.) lies at the eleventh and ninth steps respectively for these observers. The shift in the subjective reports is five steps down for *W* and seven steps down for *D*. While this effect is not so pronounced in the results of *F*, the same general tendency is to be observed. His results in the 'objective' classification are bi-modular,—an apex occurs at the thirteenth and sixteenth steps. In the 'subjective' classification the apex is at the eleventh step, so that the same downward tendency is also evidenced in his data. Over 50 per cent. of the objective reports for *W* and *F* and over 75 per cent. of them for *D* are above the respective modes of the subjective reports. These results seem to indicate that the subjective reports are as a rule cognitively less clear than the objective.[1]

B. Attributive Classification

As we said in our earlier report, the observers were not always able, because of the complexity of the problem, to carry abreast the dual task laid upon them; that is, they were not always able to note meaning and process and to give a full account of both. They tended to concentrate either upon the fulfillment of the first part of their instructions,[2] in which case the description of process was vague and uncer-

[1] No one, in the work upon imagery and the differentiation of it from sensation, has ventured to suggest that the differences may in part be due to cognition. In view of the results of this study, though confessedly we were working at a higher psychological level than sensation—still in this connection it should be recalled that Britz thought he was working at the elementary level and chose his stimuli, the colored rectangles, with that idea in mind—we nevertheless hazard the opinion that cognition plays an important rôle in the differentiation of sensation and image.

[2] *Op. cit.*, 187.

tain, or on the introspection of process, in which case the statements of meaning were neglected and incomplete.[1]

Consequently, in some of the experiments, no mention was made of attributive clearness. These cases appear in the tables under the caption 'Clearness not Reported.' In other experiments clearness was reported at one level, at two levels, and by *W* in a few instances at three levels. There was, however, but one case in which a subjective report was given in a three-level consciousness. As a matter of economy of space we have grouped this case with those of the lower level of the dual formation; we are justified in this procedure by the fact that the three-level report proved upon analysis to be cognitive and not attributive. A note of the inclusion is made at the foot of all of the tables in which it appears.

1. *Clearness not Reported.*—Examples of the introspections in which subjective reports occurred, and in which the description of attributive clearness was omitted, are:

W (77). (Card of Series I., 5 rectangles.) "Orange, last to left, reddish, good chroma, medium tint; blue, next to orange, good chroma, medium tint; yellow, last to right, slightly greenish, poor chroma, very light tint; three other colors. I nearly forgot the O and B before I got them written down. The name 'orange' was kinæsthetically inhibited for some reason and for an instant all memory of the experience faded out. No clearness reports. I am certain of the descriptions however."

F (50). (Card of Series II., 6 rectangles.) "P, O, B, Y, and four other colors. My impression is of seven areas. All of the qualities named were particularized. B was dark but was not the Milton-Bradley blue; P was, I think, quite bluish; O and Y were ordinary, but were noted as being ordinary, not merely taken for granted or merely named. It seems very queer, but simply by the time I come to report I cannot say whether all the colors were on the upper level or not. I cannot even say whether there were differences of clearness among the four described."

D (217). (Card of Series II.) "Cognized from left to right; 1. red, good chroma, bright cherry red; 2. yellow, bright; 3. quality apprehended but cannot name it; 4. yellow, bright golden quality, brighter than that of 2; 5 and 6. dim awareness of these areas; 7. blue, cognized general hue, nothing else. Cognitively there were many degrees of clearness, but cannot report on the attributive clearness of these experiences."

2. *Clearness One Level.*—Examples of the introspections in which the subjective reports occurred, and in which the clearness was said to be of one level, the upper, are:

[1] *Op. cit.*, 196.

W (27). (Card of Series II.) "Yellow, cannot describe it further; blue, good blue, rather dark; green, good chroma, medium tint, I think; and four others. There must have been seven colors in all. . . . Total field was clear."

F (41). (Card of Series I.) "Y, R, G, —, —, B. I think there were 6 colored rectangles and that all were on upper level of clearness. . . ."

(44). (Again, since over two thirds of *F*'s reports, both objective and subjective, were of this nature.) "Seven colors, all at upper level."

D (221). (Card of Series II.) "Seven colored areas. Cognized from left to right: B, Bk, —, Gy, —, —, Y. B, merely the general hue; Bk, only a dark shade; Gy, medium, cognitively clearest of all, definitely bounded and a rough paper quality; Y, bright, without form, only a quality and tint. The sensations though equally clear were not maximally clear."

3. *Clearness Two Levels.*—Examples of the introspection in which subjective reports occurred, and in which the attributive clearness of the processes at the time of the exposure was said to be of two levels, are:

W (17). (Card of Series II.) "Blue, light tint, fair chroma; orange, medium tint, good chroma. Five other colors, seven in all. B and O were clearer during the exposure than the other colors."

F (152). (Card of Series II.) "Seven colored rectangles: B, —, —, G, Bk, P, —. G and Bk were clearer and held my attention longer than the others. Bk was a velvet Bk, G was rich, possibly very slightly yellowish, medium tint. P and B merely names and were at the same level as the others indicated by dashes."

D (231). (Card of Series II.) "Seven colored rectangles. From left to right they are Y, R, B, Bk, —, —, —. Those at the left clear; those at right unclear."

A summary of the attributive classification, just mentioned and illustrated above, is given in Table I. opposite the legend 'Total.' A comparison of this summary with the similar summary of Table II. of the earier study (*op. cit.*, p. 195) reveals a striking difference between the subjective and objective reports. This is shown in Table IV., in which the numerical summaries given in the tables mentioned above are presented for comparison in the common denominator of per cent.:

TABLE IV

SHOWING THE PERCENTAGES OF OBJECTIVE AND SUBJECTIVE REPORTS IN WHICH ATTRIBUTIVE CLEARNESS WAS NOT REPORTED; IN WHICH IT WAS REPORTED AT ONE LEVEL; AND IN WHICH IT WAS REPORTED AT EITHER THE UPPER OR THE LOWER LEVEL OF THE DUAL LEVEL FORMATION

Observer	Attributive Clearness	Percentage	
		Objective Reports	Subjective Reports
W.....	Not reported.....	34.9	30.6
	One level (Upper).....	22.9	25.2
	Two levels: Upper.....	18.1[1]	....
	Lower.....	24.1	44.1[2]
F.....	Not reported.....	13.7	18.3
	One level (Upper).....	73.7	67.7
	Two levels: Upper.....	8.0	....
	Lower.....	4.6	14.0
D.....	Not reported.....	9.8	21.4
	One level (Upper).....	56.1	17.9
	Two levels: Upper.....	19.3	....
	Lower.....	14.8	60.7

The outstanding features of this table are: first, that no subjective reports are given from the upper level of clearness when the sensations aroused by the stimulus card are reported as of two levels; secondly, that there is a marked shift of the subjective reports towards the lower level. This is evinced in two ways: first by a large percentile increase, as shown by *W* and *D*, in the percentage of cases occurring at the lower level; and secondly by a large percentile increase, as shown by *F* and *D*, in the percentage of cases in which the clearness was not reported.

Of the cases in which clearness is given, 36.9 per cent. of the objective reports and 63.6 per cent. of the subjective are given by *W* from the lower clearness level; 5.3 per cent. of the objective and 17.1 per cent. of the subjective are given by *F* from the lower level; and 16.4 per cent. of the objective and

[1] *W* reported the attributive clearness of 5 experiments at 3 levels. The upper level was included here, the second and third levels were grouped with the "Lower."

[2] One case included here was reported as at the third, the lowest level of a three-level type of consciousness (*op. cit.*, p. 195).

77.2 per cent. of the subjective are given by *D* from the lower level. The percentage increase of reports at the lower level runs, for the subjective classification over that of the objective, from nearly 100 per cent. for *W* to over 300 per cent. and 400 per cent. for *F* and *D* respectively.

These data lead us to conclude that as a rule subjective are less likely than objective reports to be attributively clear.

Since the subjective reports are capable of the same classification as the objective, and since they do not show differences of kind but only differences of degree, we feel justified in concluding that Britz should not have omitted the subjective reports from his perceptual classification. Psychologically, these reports are just as good perceptions as those which have a known objective correlate.

C. Conditions of Occurrence

The second part of this paper is concerned with the questions where, when and under what conditions the subjective reports occur. Answers to these questions are given in the data which appear in Tables V., VI., VII., VIII., IX., and X.

1. *Complexity of Material.*—All of the observers, as is shown specifically by Tables V. and VIII., gave fewer subjective reports in their descriptions of the 5 than in their descriptions of the 6 figure cards. 66, 86, and 89 per cent. of the reports were given by *W*, *F*, and *D*, respectively, after the exposure of the six-figure cards of Series II. Complexity of material therefore seems to be a condition of subjectivity. This conclusion is borne out by a further analysis of the case records. Table V., under the caption 'Number Added,' shows that more dual additions were given with Series II. than with Series I. After the exposure of cards of Series I., *W*, *F*, and *D* gave respectively 4, 1, and 0 cases of dual additions, whereas they gave, after the exposure of cards of Series II., 16, 15, and 1. The only triple addition reported was by *F*, and this was given after an exposure of a six-figure card (Series II.). These data indicate, therefore, that complexity of material is a condition of subjectivity which is

effective in two ways: (1) by an increase in the total number of additions; and (2) by an increase in the number of dual or multiple additions.[1]

TABLE V

SHOWING A DIVISION AND CLASSIFICATION OF THE SUBJECTIVE REPORTS ACCORDINGLY AS THEY WERE GIVEN AFTER THE EXPOSURE OF CARDS OF SERIES I. AND OF SERIES II., AND ACCORDING TO THE NUMBER GIVEN, TO THE NUMBER ADDED, TO THE POSITION OF THOSE ADDED; ALSO SHOWING THE POSITION OF THE FIXATION, THE ORDER OF REPORT, AND THE DURATION OF THE EXPOSURE IN THE EXPERIMENTS IN WHICH SUBJECTIVE REPORTS WERE GIVEN

Observer.	Series.	Subjective Reports.		Number Added.			Position of Subjective Reports.				Fixation during Exposure.				Order of Report.				Duration of Exposure.					
		No.	%	1	2	3	Not Given.	Left.	Center.	Right.	Not Given.	Left.	Center.	Right.	Not Given.	From Left.	From Center.	From Right.	*a*	*b*	*c*	*d*	*e*	*f*
W...	I.....	37	33	29	4	0	12	19	4	2					3	4	12	14	4	8	6	8	5	2
	II.....	74	66	42	16	0	10	42	14	8					6	6	27	19	11	1	09	9	10	9
	Total .	111		71	20	0	22	61	18	10					9	10	39	33	15	18	15	17	15	11
F...	I.....	13	14	11	1	0	1	0	0	12	4	0	7	1	0	6	5	1	3	3	1	2	1	2
	II.....	80	86	47	15	1	6	3	1	70	17	1	44	1	12	5	45	1	12	9	8	11	14	9
	Total .	93		58	16	1	7	3	1	82	21	1	51	2	2	11	50	2	15	12	9	13	15	11
D...	I.....	3	11	3	0	0	0	1	0	2	2	0	1	0	0	2	1	0	1	0	0	1	0	1
	II.....	25	89	23	1	0	0	5	3	17	9	2	13	0	0	17	6	1	4	4	3	4	6	3
	Total .	28		26	1	0	0	6	3	19	11	2	14	0	0	19	7	1	5	4	3	5	6	4

2. *Position of the Subjective Reports.*—The figures given in Table V. under the caption 'Position of the Subjective Reports' show the number of times that position is not clearly indicated, and the number of times that subjective reports are given at the left, the center, and at the right of the perceptual field.

These data show a 'position of subjectivity'—a position which, for reasons we shall presently consider, is particularly

[1] What is the exact relation, and whether the number of subjective reports varies directly or according to the logarithm of some constant with the number of objective stimuli, are questions which can not now be answered. That some relation does exist, that the number reported is in some way correlated with the number exposed, is quite evident from our results. We hope to return to these questions and to make them the object of a separate study.

favorable for the perception of additional areas. This position is at the left for *W* and at the right for *F* and *D*. It is not affected by the complexity of the exposure material, for the same conditions obtain in the reports of Series I. as of Series II.

The factors which in this experiment condition the position of the subjective reports are:

(*a*) *Fixation.*—The position of the fixation was thought to have been stabilized by the fixation-point of the apparatus. Consequently the observers were not directed to report fixation. Two of the observers, *F* and *D*, fortunately however, gave a report of it in a large per cent. of the experiments.[1] The data for this appear in Table V. under the caption 'Fixation during Exposure.' These data show that where fixation was reported it occurred at the center of the field for both of the observers in about 90 per cent. of the experiments.

A correlation of the point of fixation with the position of the subjective report is given in Table VI. The correlation shows a negative relation. With but 2 exceptions for each observer, subjective reports do not occur at the position of fixation. For example: when *F*'s fixation is at the left no subjective reports are given at the left, though 2 are reported at the right; when his fixation is at the center, no cases are reported at the center, though 2 are reported at the left and

TABLE VI

SHOWING THE CORRELATION BETWEEN THE POINT OF FIXATION AND THE POSITION OF THE SUBJECTIVE REPORT

Observer	Position of Subjective Report	Point of Fixation				Total
		Not Reported	Left	Center	Right	
F.....	Not reported.....	2	0	5	0	7
	Left.....	1	0	2	0	3
	Center.....	0	0	0	1	1
	Right.....	25	2	53	2	82
	Total.....	28	2	60	3	93
D.....	Not reported.....	0	0	0	0	0
	Left.....	2	0	4	0	6
	Center.....	1	0	2	0	3
	Right.....	8	2	9	0	19
	Total.....	11	2	15	0	28

[1] *Op. cit.*, 206, 216.

53 at the right; when his fixation is at the right, however, there is an exception to this rule, for 2 of the 3 cases given here are reported as at the right, while the third is reported as at the center.

These exceptions and the concentration of the subjective cases at the right for *F* and *D* show the influence of other factors.

(*b*) *Clearness.*—Attributive clearness conditions subjectivity in the same manner as fixation conditions it; namely, by acting negatively. The table which gives the position of the upper level of clearness in those experiments in which the dual formation is reported, and the table which gives the correlation between the upper level and the 'position of subjectivity,' reveal that no subjective reports were given in the upper level; that, conversely stated, a one-to-one correlation exists between the position of the subjective report and the position of the lower clearness level. These tables have been omitted from this paper, since the facts are given in Table I. above, which shows that subjective reports are given—when the dual formation is reported—only at the lower level. Attributive clearness therefore sufficiently accounts for the exceptions noted above, and for the concentration of the subjective cases at the right in so far as the subjective reports are given in the dual formation; but this explanation does not of course apply to those cases in which all of the processes are reported as of one level of clearness.

(*c*) *Order of Report.*—The order of reporting we think accounts for the 'position of subjectivity,' in so far as it is not conditioned by fixation and clearness; for, as we stated in our earlier study,[1] and as is shown in Table V. above, all three observers were consciously disposed to a definite order of report: *W* was set to report from the right; *F* from the center, first toward the left and then toward the right; and *D* was set to report as in reading from the left to the right; and the subjective reports, as we have shown above, are grouped at those areas that the observers came to last in their descriptions.

[1] *Op. cit.*, 218.

Table VII. shows the correlation between the order of reporting and the position of the subjective reports.

TABLE VII

SHOWING THE CORRELATION BETWEEN THE ORDER OF REPORT AND THE POSITION OF THE SUBJECTIVE REPORT

Observer	Position of Subjective Report	Order of Report				Total
		Not Reported	From Left	From Center	From Right	
W.....	Not reported.....	1	3	8	10	22
	Left.....	4	4	31	22	61
	Center.....	5	5		8	18
	Right.....	1	1	5	3	10
	Total.....	11	13	44	43	111
F.....	Not reported.....		2	5		7
	Left.....	1		2		3
	Center.....				1	1
	Right.....	16	13	51	2	82
	Total.....	17	15	58	3	93
D.....	Not reported.....					0
	Left.....		1	4	1	6
	Center.....		3			3
	Right.....		15	3	1	19
	Total.....		19	7	2	28

This table shows that the subjective reports seldom occur in the areas which were first described. For example: when *W* began his report at the left, only 4 out of 13 subjective cases were reported at the left; when he began them at the center, not one out of 44 cases was reported at the center; and when he began his reports at the right, only 3 out of 43 cases were reported at the right. Similarly for *F* and *D*: *F* began his reports from the center 58 times, a subjective report was given at the center but once; he began his reports from the right but twice, 82 subjective reports were given at the right. *D* began his reports from the left 19 times, subjective reports were given at the left 6 times; he began his reports at the right twice, 19 subjective reports were given at the right.

It might be argued that the order of reporting, instead of being a condition of the 'position of subjectivity,' is itself

conditioned by the position of the subjective report. This objection might be pertinent were it not for the fact that the 'Order of Report' was the same for the 'objective' experiments (experiments in which no subjective report occurred) as for the 'subjective' experiments.[1] That being the case, 'position of subjectivity' could hardly act as a determinant of the order of report. Hence we feel justified in regarding the general tendency to name in a certain direction from certain fixed points as a factor which conditions the position at which the subjective cases are reported.

3. *Duration of Exposure.*—The relation of the subjective reports to the time of exposure is shown in Table V. under the caption 'Duration of Exposure.' The letters at the top of the table denote the exposure times employed.[2] These times varied by intervals of 40σ; extending from 40σ the shortest—exposure *a*, to 240σ the longest—exposure *f*.

These data show that the exposure times have no effect upon subjectivity. Subjective reports are given in the descriptions which follow long exposures as often as in the descriptions which follow medium and short exposures. The differences are too slight to be significant, nor are they constant or in the same direction.

4. *Quality.*—It was thought that quality would affect both the number and the position of the subjective reports. We had come to this conclusion from casual observation, for we had frequently noticed in running through the introspections that subjective reports were given in the experiments in which tints and colors of poor saturation were used. If this were the case, if certain colors or color combinations were effective subjectively, we should then expect to find that subjective reports were always given when certain stimulus cards, and never given when other cards, were used.

Table VIII. shows the number of times subjective reports were given for the various stimulus cards.

These data reveal how groundless was our opinion that certain qualities or certain combinations of qualities con-

[1] *Op. cit.*,

[2] *Cf. op. cit.*, 186.

ditioned subjective reports. The occurrence is too evenly distributed throughout the list of stimulus cards to be of any significance. Such variations as occur in Table VIII. must be regarded as due to chance only.

TABLE VIII

SHOWING THE NUMBER OF TIMES THE SUBJECTIVE REPORTS WERE GIVEN FOR THE VARIOUS STIMULUS CARDS

Series	Observer	Card Number																			Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
I.....	*W*.....	1	1	1		2	2	2	2	1	1	4	2	2	2	2	1	3		2	2	33
	F.....	1	1		1	2					1	1			1	2		1		1		12
	D.....					1						1	1									3
	Total.....	2	2	1	1	5	2	2	2	1	2	6	3	2	3	4	1	4	0	3	2	48
II.....	*W*.....	1	4	3	5	4	5	5	3	4	3	4	2	1	2	2	1		2	4	3	58
	F.....	3	3		4	4	5	4	4	3	2	4	4	1	2	2	5	3	4	3	3	63
	D.....	2	1	2	1		1	2	1	2	2	1	2	1	1	1	2	1		1		24
	Total.....	6	8	5	10	8	11	11	8	9	7	9	8	3	5	5	8	4	6	8	6	145

Note.—For the specific qualities used and for the selection and arrangement of them on the exposure cards see the earlier study (the footnote to p. 184, and the Table on p. 185).

5. *Practice.*—The effect of practice in the apprehension and description of the exposure cards upon the subjective reports is shown in Table IX.

TABLE IX

SHOWING THE NUMBER OF EXPERIMENTS IN WHICH SUBJECTIVE REPORTS WERE GIVEN DURING THE DIFFERENT PARTS OF THE RESEARCH

Observer	Experiments			Total
	1–80	81–160	161–240	
W.....	29	32	30	91
F.....	23	27	25	75
D.....	6	7	14	27

These data show that the subjective reports for *W* and *F* were distributed evenly throughout the course of the exper-

iment. Practice therefore had no effect for these observers. *D*'s data, on the contrary, show a gradual increase in the number of experiments in which subjective reports were given. They occur in 6 of the first 80 experiments, in 7 of the second 80, and in 14 of the last 80 experiments. The number of cases is so few and the absolute difference in the distribution is so small that we are, particularly in view of *W*'s and *F*'s results, inclined to the opinion that the variation is due to chance. If this view be rejected, the following fact should be considered before ascribing the distribution to practice: *D* constructed the exposure cards and was thus familiar with the number and quality of the stimuli used. This positive knowledge may have consciously at some times and unconsciously at others limited his descriptions. During the early experiments the effect of this knowledge would be the greatest, and his descriptions would be comparatively free from subjective reports. As time passed, and his memory of the cards faded, and the principles upon which he had constructed them became less clear, his reports would gradually approach the norm, and subjective reports would appear more and more frequently. From this point of view the increase shown in *D*'s data is due to habituation, to an unprejudiced approach to the problem of describing the exposure card.

6. *Fatigue.*—In order to discover the effect of fatigue the observation hour was divided into three equal parts and the experiments in which subjective reports were given were counted separately in every part. Table X. shows the results of this division and computation.

TABLE X

SHOWING THE NUMBER OF EXPERIMENTS IN WHICH SUBJECTIVE REPORTS WERE GIVEN DURING THE DIFFERENT PARTS OF THE OBSERVATION HOUR

Observer	Third fractional part of the hour			Total
	1	2	3	
W	30	30	31	91
F	25	25	25	75
D	9	10	8	27

The table shows that the subjective reports are distributed evenly for all observers throughout the observation hour and that therefore they are in no way conditioned upon or affected by fatigue.

Summary

The results of this paper may be summarized as follows:

1. The subjective reports were classified upon the perceptual scale obtained in the earlier work. No differences of kind were noted; all the cases fell readily into the cognitive classification. Differences of degree, however, as indicated by the limited range and by the fact that the highest steps were rarely represented, were noted. We are therefore led to the conclusion that 'subjective' reports are as a rule cognitively less clear than 'objective.'

2. The subjective reports were also classified upon the basis of attributive clearness. The same results were obtained as in the earlier work. The experiments were classified into those cases in which clearness was not mentioned—it was not under the conditions of the experiment reportable; into those in which one level was reported; and into those in which two levels were reported. The outstanding difference between the attributive classification of the 'subjective' and 'objective' reports is that no subjective report was given from the upper level of clearness when the dual formation was reported. Our conclusion is, therefore, that subjective reports are less likely than objective to be attributively clear.

3. Since the subjective reports are capable of the same classification as the objective, and since they do not show differences of kind but only differences of degree, they should not be omitted from a perceptual classification upon the ground that they have no known objective correlate.

4. Complexity of material, of all the factors considered, was found to be the only one which conditioned the subjective reports. This was effective in two ways: (1) by an increase in the total number of additions; and (2) by an increase in the number of dual and multiple additions.

5. Under the conditions of this experiment, the duration of the exposure, the quality and the arrangement of the stimuli on the exposure cards, practice, and fatigue have no effect upon the occurrence or the distribution of the subjective reports.

6. Subjective reports occurred more frequently in some areas of the field than in others. The position of this 'area of subjectivity' was different for the observers; it was an individual difference which, however, could be explained and determined by fixation, by the position of the upper level of attributive clearness, and by 'set,' that is, by the general tendency to report in certain directions from certain fixed points.